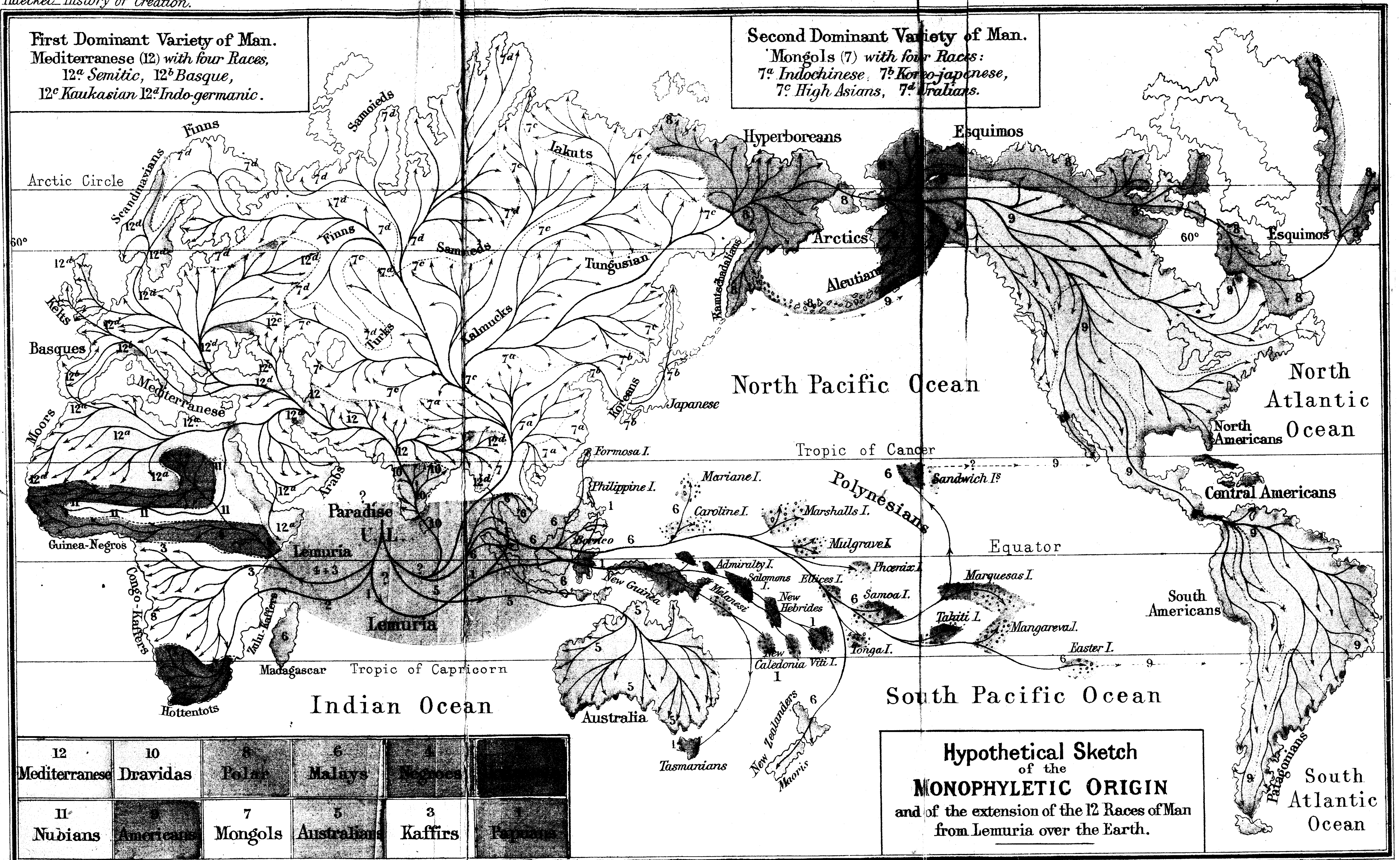
First Dominant Variety of Man.
Mediterranese (12) with four Races,
12a Semitic, 12b Basque,
12c Kaukasian 12d Indo-germanic.
Second Dominant Variety of Man.
Mongols (7) with four Races:
7a Indochinese, 7b Koreo-japanese,
7c High Asians, 7d Uralians.
Arctic Circle
Finns
Scandinavians
Samoieds
Iakuts
Hyperboreans
Esquimos
Kelts
Basques
Moors
Mediterranese
Arabs
Turks
Kalmucks
Tungusian
Kamtschadalians
Arctics
Aleutians
Koreans
Japanese
North Pacific Ocean
Tropic of Cancer
Formosa I.
Philippine I.
Mariane I.
Caroline I.
Marshalls I.
Mulgrave I.
Polynesians
Sandwich Is
Paradise
Lemuria
Guinea-Negros
Congo-Kaffers
Zulu-Kaffers
Madagascar
Hottentots
Tropic of Capricorn
Indian Ocean
Borneo
New Guinea
Admiralty I.
Salomons I.
Melanesi
New Hebrides
New Caledonia
Viti I.
Ellices I.
Phoenix I.
Samoa I.
Tonga I.
Marquesas I.
Tahiti I.
Mangareva I.
Easter I.
Equator
Australia
Tasmanians
New Zealanders
Maoris
South Pacific Ocean
North Americans
North Atlantic Ocean
Central Americans
South Americans
Patagonians
South Atlantic Ocean
12 Mediterranese
10 Dravidas
8 Polar
6 Malays
4 Negroes
11 Nubians
9 Americans
7 Mongols
5 Australians
3 Kaffirs
1 Papuans
Hypothetical Sketch of the MONOPHYLETIC ORIGIN and of the extension of the 12 Races of Man from Lemuria over the Earth.

THE

HISTORY OF CREATION

OR THE DEVELOPMENT OF THE EARTH AND ITS INHABITANTS BY THE ACTION OF NATURAL CAUSES

A POPULAR EXPOSITION OF
THE DOCTRINE OF EVOLUTION IN GENERAL, AND OF THAT OF
DARWIN, GOETHE, AND LAMARCK IN PARTICULAR

FROM THE EIGHTH GERMAN EDITION OF
ERNST HAECKEL
PROFESSOR IN THE UNIVERSITY OF JENA

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IN TWO VOLUMES.—VOL. II.

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A sense sublime
Of something far more deeply interfused,
Whose dwelling is the light of setting suns,
And the round ocean, and the living air,
And the blue sky, and in the mind of man ;
A motion and a spirit that impels
All thinking things, all objects of all thought,
And rolls through all things.

In all things, in all natures, in the stars
Of azure heaven, the unenduring clouds,
In flower and tree, in every pebbly stone
That paves the brooks, the stationary rocks,
The moving waters and the invisible air.

WORDSWORTH.

CONTENTS OF VOL. II.

CHAPTER XVI.

PERIODS OF CREATION AND RECORDS OF CREATION.

CHAPTER XVII.

PHYLOGENETIC SYSTEM OF ORGANISMS: PROTISTA AND HISTONS.

CHAPTER XX.

PHYLOGENETIC CLASSIFICATION OF THE ANIMAL KINGDOM. THE GASTRÆA THEORY.

CHAPTER XXI.

PEDIGREE AND HISTORY OF CŒLENTERIA AND WORMS.

CHAPTER XXII.

PEDIGREE AND HISTORY OF THE MOLLUSCS AND STAR-FISHES.

CHAPTER XXIII.

PEDIGREE AND HISTORY OF THE ARTICULATED ANIMALS.

CHAPTER XXIV.

PEDIGREE AND HISTORY OF THE CHORDONIA, OR CHORDATA.

The Tunicates and Vertebrates.

CHAPTER XXV.

HISTORY AND PEDIGREE OF THE AMPHIBIA AND AMNIOTA.

CHAPTER XXVIII.

MIGRATION AND DISTRIBUTION OF MANKIND. HUMAN SPECIES AND HUMAN RACES.

CHAPTER XXIX.

OBJECTIONS AGAINST THE THEORY OF DESCENT.

CHAPTER XXX.

PROOFS OF THE TRUTH OF THE THEORY OF DESCENT.

LIST OF ILLUSTRATIONS.

PLATES.

FIGURES.

THE HISTORY OF CREATION.

CHAPTER XVI.

PERIODS OF CREATION AND RECORDS OF CREATION.

Reform of Systems by the Theory of Descent.—The Natural System as a Pedigree.—Palæontological Records of the Pedigree.—Petrifactions as Records of Creation.—Deposits of the Neptunic Strata and the Enclosure of Organic Remains.—Division of the Organic History of the Earth into Five Main Periods: Period of the Tangle Forests, Fern Forests, Pine Forests, Foliaceous Forests, and of Cultivation.—The Series of Neptunic Strata.—Immeasurable Duration of the Periods which have elapsed during their Formation.—Deposits of Strata only during the Sinking, not during the Elevation of the Ground.—Other Gaps in the Records of Creation.—Metamorphic Condition of the most Ancient Neptunic Strata.—Small Extent of Palæontological Experience.—Small Proportion of Organisms and of Parts of Organisms Capable of Petrifying.—Rarity of many Petrified Species.—Want of Fossilized Intermediate Forms.—Records of the Creation in Ontogeny and in Comparative Anatomy.

THE historical conception of organic life which has been introduced into biological science by the Theory of Descent affects no branch of science, excepting Anthropology, so much as the descriptive portion of natural history, that which is known as systematic Zoology and Botany. Most naturalists who have hitherto occupied themselves with arranging the different systems of animals and plants, have collected, named, and arranged the different species of these

natural bodies with much the same interest as antiquarians and ethnographers collect the weapons and utensils of different nations. Many have not even risen above the degree of intelligence with which people usually collect, label, and arrange crests, stamps, and similar curiosities. In the same manner as these collectors find their pleasure in the similarity of forms, the beauty or rarity of the crests or stamps, and admire in them the inventive art of man, so many naturalists take a delight in the manifold forms of animals and plants, and marvel at the rich imagination of the Creator, at His unwearied creative activity, and at His curious fancy for forming, by the side of so many beautiful and useful organisms, also a number of ugly and useless ones.

This childlike treatment of systematic Zoology and Botany is completely annihilated by the Theory of Descent. In the place of the superficial and playful interest with which most naturalists have hitherto regarded organic structures, we now have the much higher interest of the intelligent understanding which detects in the *related forms* of organisms their true *blood-relationships.* The *Natural System of animals and plants,* which was formerly valued either only as a registry of names, to facilitate the survey of the different forms, or as a table of contents for the short expression of their degrees of similarity, receives from the Theory of Descent the incomparably higher value of a true *pedigree of organisms.* This pedigree is to disclose to us the genealogical connection of the smaller and larger groups. It has to show us in what way the different classes, orders, families, genera, and species of the animal and vegetable kingdoms correspond with the different branches, twigs, and groups of

twigs of the pedigree. Every wider and higher category or stage of the system (for example, a class, or an order) comprises a number of larger and stronger branches of the pedigree; every narrower and lower category (for example, a genus, or a species) only a smaller and thinner group of twigs. It is only when we thus view the natural system as a pedigree that we perceive its true value.

This genealogical conception of the organic system doubtless belongs to futurity alone. But with it as our basis we may now turn our attention to one of the most essential, but also one of the most difficult, tasks of the "non-miraculous history of creation," namely, to the actual construction of the Organic Pedigree. Let us see how far we are already able to point out all the different organic forms as the divergent descendants of a single or of some few common original forms. But how can we construct the actual pedigree of the animal and vegetable group of forms from our knowledge of them, at present so scanty and fragmentary? The answer to this question lies in what we have already remarked of the parallelism of the three series of development—in the important causal relation which connects the palæontological development of all organic tribes with the embryological development of individuals, and with the systematic development of groups.

In order to accomplish our task we shall first have to direct our attention to *palæontology*, or *the science of petrifactions*. For if the Theory of Descent is really true, if the petrified remains of formerly living animals and plants really proceed from the extinct primæval ancestors and progenitors of the present organisms, then, without anything else, the knowledge and comparison of petrifactions

ought to disclose to us the pedigree of organisms. However simple and clear this may seem in theory, the task becomes extremely hard and complicated when it is actually taken in hand. Its practical solution would be very difficult even if the petrifactions were to any extent completely preserved. But this is by no means the case. The obvious records of creation which lie buried in petrifactions are imperfect beyond all measure. Hence it is necessary critically to examine these records, and to determine the value which petrifactions possess for the history of the development of organic tribes. As I have previously discussed the general importance of petrifactions as the records of creation, when we were considering Cuvier's merits in the science of fossils, we may now at once examine the conditions and circumstances under which the remains of organic bodies became petrified and preserved in a more or less recognizable form.

As a rule, we find petrifactions or fossils enclosed only in those stones which have been deposited in layers as mud by water, and which are on that account called neptunic, stratified, or sedimentary rocks. The deposition of such strata could of course only commence after the condensation of watery vapour into liquid water had taken place in the course of the earth's history. After that period, which we considered in our last chapter, not only did life begin on the earth, but also an uninterrupted and exceedingly important transformation of the rigid inorganic crust of the earth. The water began that extremely important mechanical action by which the surface of the earth is perpetually, though slowly, transformed. I may surely presume that it is generally known what an extremely important influence, in this respect, is even yet exercised by water at every

moment. As it falls down as rain, trickling through the upper strata of the earth's crust, and flowing down from heights into hollows, it chemically dissolves different mineral parts of the ground, and mechanically washes away the loose particles. In flowing down from mountains water carries their *débris* into the plains, or deposits it as mud in stagnant lakes. Thus it continually works at lowering mountains and filling up valleys. In like manner the breakers of the sea work uninterruptedly at the destruction of the coasts and at filling up the bottom of the sea with the *débris* they wash down. The action of water alone, if it were not counteracted by other circumstances, would in time level the whole earth. There can be no doubt that the mountain masses—which are annually carried down as mud into the sea, and deposited on its floor—are so great that in the course of a longer or shorter period, say a few millions of years, the surface of the earth would be completely levelled and become enclosed by a continuous sheet of water. That this does not happen is owing to the perpetual volcanic action of the fiery-fluid centre of the earth. The surging of the melted nucleus against the firm crust necessitates continual alternations of elevation and depression on the different parts of the earth's surface. These elevations and depressions for the most part take place very slowly; but, as they continue for thousands of years, by the combined effect of small, interrupted movements, they produce results no less grand than does the counteracting and levelling action of water.

Since the elevations and depressions of the different parts of the earth alternate with one another in the course of millions of years, first this and then that part of the earth's

surface is above or below the level of the sea. I have already given examples of this in the preceding chapter (vol. i. p. 376). Hence, in all probability, there is no part of the outer crust of the earth which has not been repeatedly above and also below the level of the sea. This repeated change explains the variety and the different composition of the numerous neptunic strata of rocks, which in most places have been deposited one above another in considerable thickness. In the different periods of the earth's history during which these deposits took place there lived various and different populations of animals and plants. When their dead bodies sank to the bottom of the waters, the forms of the bodies impressed themselves upon the soft mud, and imperishable parts, such as hard bones, teeth, shells, etc., became enclosed in it uninjured. These were preserved in the mud, which condensed them into neptunic rock, and as petrifactions they now serve to characterize the respective strata. By a careful comparison of the different strata lying one above another, and the petrifactions preserved in them, it has become possible to decide the relative age of the strata and groups of strata, and to establish, by direct observation, the principal eras of phylogeny, that is to say, the stages in history of the development of animal and vegetable tribes.

The different strata of neptunic rocks deposited one above another, which are composed in very various ways of limestone, clay, and sand, geologists have grouped together into an ideal System or Series, which corresponds with the whole course of the organic history of the earth, or with that portion of the earth's history during which organic life existed. Just as so-called "universal history" falls into larger and smaller

periods, which are characterized by the conditions of development of the most important nations at the respective epochs, and are separated from one another by great events, so we also divide the infinitely longer organic history of the earth into a series of greater and less periods. Each of these periods is distinguished by a characteristic flora and fauna, and by the specially strong development of certain vegetable or animal groups, and each is separated from the preceding and succeeding period by a striking change in the character of its animal and vegetable inhabitants.

In relation to the following survey of the historical course of development which the large animal and vegetable tribes have passed through, it will be desirable to say a few words first as to the systematic classification of the neptunic groups of strata, and the larger and smaller periods corresponding to them. As will be seen directly, we are able to divide the whole of the sedimentary rocks lying one above another into five main groups or periods, each period into several subordinate groups of strata or *systems*, and each system of strata again into still smaller groups or *formations;* finally, each formation can again be divided into stages or sub-formations, and each of these again into still smaller layers or beds. Each of the five great rock-groups was deposited during a great division of the earth's history, during a long *era* or *epoch;* each system during a shorter *period;* each formation during a still shorter *period.* In thus reducing the periods of the organic history of the earth, and the neptunic strata containing petrifactions deposited during those periods, into a connected system, we proceed exactly like the historian who divides the history of nations into the three main divisions of Antiquity,

the Middle Ages, and Modern Times, and each of these sections again into subordinate periods and epochs. But the historian by this sharp systematic division, and by fixing the boundary of the periods by particular dates, only seeks to facilitate his survey, and in no way means to deny the uninterrupted connection of events and the development of nations. Exactly the same qualification applies to our systematic division, specification, or classification of the organic history of the earth. Here, too, a continuous thread runs through the series of events unbroken. We must therefore distinctly protest against the idea that by sharply bounding the larger and smaller groups of strata, and the periods corresponding with them, we in any way wish to adopt Cuvier's doctrine of terrestrial revolutions, and of repeated new creations of organic populations. That this erroneous doctrine has long since been completely refuted by Lyell, I have already mentioned.

The five great main divisions of the organic history of the earth, or the palæontological history of development, we call the primordial, primary, secondary, tertiary, and quaternary epochs. Each is distinctly characterized by the predominating development of certain animal and vegetable groups in it, and we might accordingly symbolically designate the five epochs, on the one hand by the names of the groups of the vegetable kingdom, and on the other hand by those of the different classes of vertebrate animals. In this case the *first,* or primordial epoch, would be the era of the Tangles (Algæ) and skull-less Vertebrates; the *second,* or primary epoch, that of the Ferns and Fishes; the *third,* or secondary epoch, that of Pine Forests and Reptiles; the *fourth,* or tertiary epoch, that of Foliaceous Forests and of

Mammals; finally, the *fifth*, or quaternary epoch, the era of Man and his Civilization. The divisions or *periods* which we distinguish in each of the five *long eras* (p. 14) are determined by the different *systems* of strata into which each of the five great *rock-groups* is divided (p. 15). We shall now take a cursory glance at the series of these systems, and at the same time at the populations of the five great epochs.

The first and longest division of the organic history of the earth is formed by the *primordial epoch*, or *the era of the Tangle Forests.* It comprises the immense period from the first spontaneous generation, from the origin of the first terrestrial organism, to the end of the Silurian system of deposits. During this immeasurable space of time, which in all probability was much longer than all the other four epochs taken together, the three most extensive of all the neptunic systems of strata were deposited, namely, the *Laurentian*, upon that the *Cambrian*, and upon that the *Silurian* system. The approximate thickness or size of these three systems together amounts to 70,000 feet. Of these about 30,000 belong to the Laurentian, 18,000 to the Cambrian, and 22,000 to the Silurian system. The average thickness of all the four other rock-groups, the primary, secondary, tertiary, and quaternary, taken together, may amount at most to 60,000 feet; and from this fact alone, apart from many other reasons, it is evident that the duration of the primordial period was probably much longer than the duration of all the subsequent periods down to the present day. Many thousands of millions of years were required to deposit such masses of strata. Unfortunately, by far the largest portion of the primordial group of strata

is in the metamorphic state (which we shall directly explain), and consequently the petrifactions contained in them—the most ancient and most important of all—have, to a great extent, been destroyed and become unrecognizable. Only in one portion of the Cambrian and Silurian strata have petrifactions been preserved in a recognizable condition and in large quantities. The most ancient of all distinctly preserved petrifactions is the so-called "Canadian Life's-dawn" (Eozoon canadense), the organic nature of which (as Polythalamia) is still doubtful, and disputed in various quarters. It was found in the lowest Laurentian strata (in the Ottawa formation, on the St. Lawrence).

Although only by far the smaller portion of the primordial or archilithic petrifactions are preserved to us in a recognizable condition, still they possess the value of inestimable documents of the most ancient and obscure times of the organic history of the earth. What seems to be shown by them, in the first place, is that during the whole of this immense period there existed only inhabitants of the waters. As yet, at any rate, among all archilithic petrifactions, not a single one has been found which can with certainty be regarded as an organism which has lived on land. All the vegetable remains we possess of the primordial period belong to the lowest of all groups of plants, to the class of Tangles or Algæ, living in water. In the warm primæval sea, these constituted the forests of the primordial period, of the richness of which in forms and density we may form an approximate idea from their present descendants, the tangle forests of the Atlantic Sargasso sea. The colossal tangle forests of the archilithic period supplied the place of the forest vegetation of the mainland, which was then utterly

wanting. All the animals, also, whose remains have been found in archilithic strata, like the plants, lived in water. Only crustacea are met with among the animals with articulated feet and some scorpions, but no insects. Of vertebrate animals, only a very few remains of fishes are known as having been found in the most recent of all primordial strata, in the upper Silurian. But the headless vertebrate animals, which we call *skull-less*, or *Acrania*, and out of which fishes must have been developed, we suppose to have lived in great numbers during the primordial epoch. Hence we may call it after the *Acrania* as well as after the *Tangles*.

The *primary epoch*, or *the era of Fern Forests*, the second main division of the organic history of the earth, which is also called the palæolithic or palæozoic period, lasted from the end of the Silurian formation of strata to the end of the Permian formation. This epoch was also of very long duration, and again falls into three shorter periods, during which three great systems of strata were deposited, namely, first, the *Devonian* system, or the old red sandstone; upon that, the *Carboniferous*, or coal system; and upon this, the *Permian* system. The average thickness of these three systems taken together may amount to about 42,000 feet, from which we may infer the immense length of time requisite for their formation.

The Devonian and Permian formations are especially rich in remains of fishes, of primæval fish as well as enamelled fish (Ganoids), but the bony fish (Téleostei) are absent from the strata of the primary epoch. In coal are found the most ancient remains of animals living on land, both of articulated animals (spiders and insects) as well as of verte-

brate animals (amphibious animals). In the Permian system there occur, in addition to the amphibious animals, the more highly developed reptiles, and, indeed, forms nearly related to our lizards (Proterosaurus, etc.). But, nevertheless, we may call the primary epoch that of *Fishes,* because these few amphibious animals and reptiles are insignificant in comparison with the immense mass of palæozoic fishes. Just as Fishes predominate over the other vertebrate animals, so *Ferns,* or Filices, predominate among the plants of this epoch, and, in fact, real ferns and tree ferns (leafed ferns, or Phylopteridæ), as well as bamboo ferns (Calamophytæ) and scaled ferns (Lepidophytæ). These ferns, which grew on land, formed the chief part of the dense palæolithic island forests, the fossil remains of which are preserved to us in the enormously large strata of coal of the Carboniferous system, and in the smaller strata of coal of the Devonian and Permian systems. We are thus justified in calling the primary epoch either the era of *Ferns* or that of *Fishes.*

The third great division of the palæontological history of development is formed by the *secondary epoch,* or the *era of Pine Forests,* which is also called the mesolithic or mesozoic epoch. It extends from the end of the Permian system to the end of the Chalk formation, and is again divided into three great periods. The stratified systems deposited during this period are, first and lowest, the *Triassic* system, in the middle the *Jura* system, and at the top the *Cretaceous* system. The average thickness of these three systems taken together is much less than that of the primary group, and amounts as a whole only to about 15,000 feet. The secondary epoch can accordingly in all probability not have been half so long as the primary epoch.

Just as Fishes prevailed in the primary epoch, *Reptiles* predominated in the secondary epoch over all other vertebrate animals. It is true that during this period the first birds and mammals originated; at that time, also, there existed important amphibious animals, especially the gigantic Labyrinthodonts; and among the many primæval fishes and enamelled fish (Ganoids) of the earlier times the first genuine fish with bones are met with; but the very variously developed kinds of reptiles formed the predominating and characteristic class of vertebrate animals of the secondary epoch. Besides those reptiles which were very nearly related to the present living lizards, crocodiles, and turtles, there were, during the mesolithic period, swarms of grotesquely shaped dragons. The remarkable flying lizards, or Pterosaurii, the wonderful sea-dragons, or Halisaurii, and the colossal land-dragons, or Dinosaurii, of the secondary epoch, are peculiar, as they occur neither in the preceding nor in the succeeding epochs. The secondary epoch may be called the era of *Reptiles;* but, on the other hand, it may also be called the era of *Pine Forests*, or, more accurately, of the *Gymnosperms,* that is, the epoch of *plants having naked seeds.* For this group of plants, especially as represented by the two important classes—the pines, or *Coniferæ*, and the palm-ferns, or *Cycadeæ*—during the secondary epoch constituted a predominant part of the forests. But towards the end of the epoch (in the Chalk period) the plants of the pine tribe gave place to the leaf-bearing forests which then developed for the first time.

The fourth main division of the organic history of the earth, the *tertiary epoch*, or *era of Leafed Forests*, is much shorter and less peculiar than the three first epochs. This

SURVEY

Of the Palæontological Periods, or of the Greater Divisions of the Organic History of the Earth.

I. *First Epoch:* ARCHILITHIC ERA. *Primordial Epoch.*

(Era of Skull-less Animals and Forests of Tangles.)

1. Older Primordial Period	or	Laurentian Period.
2. Middle Primordial Period	,,	Cambrian Period.
3. Later Primordial Period	,,	Silurian Period.

II. *Second Epoch:* PALÆOLITHIC ERA. *Primary Epoch.*

(Era of Fish and Fern Forests.)

4. Older Primary Period	or	Devonian Period.
5. Mid Primary Period	,,	Coal Period.
6. Later Primary Period	,,	Permian Period.

III. *Third Epoch:* MESOLITHIC ERA. *Secondary Epoch.*

(Era of Reptiles and Pine Forests.)

7. Older Secondary Period	or	Trias Period.
8. Middle Secondary Period	,,	Jura Period.
9. Later Secondary Period	,,	Chalk Period.

IV. *Fourth Epoch:* CÆNOLITHIC ERA. *Tertiary Epoch.*

(Era of Mammals and Leaf Forests.)

10. Older Tertiary Period	or	Eocene Period.
11. Newer Tertiary Period	,,	Miocene Period.
12. Recent Tertiary Period	,,	Pliocene Period.

V. *Fifth Epoch:* ANTHROPOLITHIC ERA. *Quaternary Epoch.*

(Era of Man and Cultivated Forests.)

13. Older Quaternary Period	or	Ice or Glacial Period.
14. Newer Quaternary Period	,,	Post Glacial Period.
15. Recent Quaternary Period	,	Period of Culture.

(The Period of Culture is the Historical Period, or the Period of Tradition.)

SURVEY

Of the Palæontological Formations, or those Strata of the Earth's Crust containing Petrifactions.

Rock-Groups.	*Systems.*	*Formations.*	*Synonyms of Formations.*
V. *Quaternary Group,* or Anthropolithic (Anthropozoic) groups of strata	XIV. Recent (Alluvium)	36. *Present*	Upper alluvial
		35. *Recent*	Lower alluvial
	XIII. Pleistocene (Diluvium)	34. *Post glacial*	Upper diluvial
		33. *Glacial*	Lower diluvial
IV. *Tertiary Group,* or Cænolithic (Cænozoic) groups of strata	XII. Pliocene (Late tertiary)	32. *Arvernian*	Upper pliocene
		31. *Sub-Appenine*	Lower pliocene
	XI. Miocene (New tertiary)	30. *Falunian*	Upper miocene
		29. *Limburgian*	Lower miocene
	X. Eocene (Old tertiary)	28. *Gypsum*	Upper eocene
		27. *Nummulitic*	Mid eocene
		26. *London clay*	Lower eocene
III. *Secondary Group,* or Mesolithic (Mesozoic) groups of strata	IX. Cretaceous	25. *White chalk*	Upper cretaceous
		24. *Green sand*	Mid cretaceous
		23. *Neocomian*	Lower cretaceous
		22. *Wealden*	The Kentish Weald
	VIII. Jura	21. *Portlandian*	Upper oolite
		20. *Oxfordian*	Mid oolite
		19. *Bath*	Lower oolite
		18. *Lias*	Lias formation
	VII. Trias	17. *Keuper*	Upper trias
		16. *Muschelkalk*	Mid trias
		15. *Bunter sand*	Lower trias
II. *Primary Group,* or Palæolithic (Palæozoic) groups of strata	VI. Permian	14. *Zechstein*	Upper Permian
		13. *New red sandstone*	Lower Permian
	V. Carbonic (coal)	12. *Carboniferous sandstone*	Upper carbonic
		11. *Carboniferous limestone*	Lower carbonic
	IV. Devonian (Old red sandstone)	10. *Pilton*	Upper Devonian
		9. *Ilfracombe*	Mid Devonian
		8. *Linton*	Lower Devonian
I. *Primordial Group,* or Archilithic (Archizoic) groups of strata	III. Silurian	7. *Ludlow*	Upper Silurian
		6. *Llandovery*	Mid Silurian
		5. *Llandeilo*	Lower Silurian
	II. Cambrian	4. *Potsdam*	Upper Cambrian
		3. *Longmynd*	Lower Cambrian
	I. Laurentian	2. *Labrador*	Upper Laurentian
		1. *Ottawa*	Lower Laurentian

epoch, which is also called the cænolithic or cænozoic epoch, extended from the end of the cretaceous system to the end of the pliocene system. The strata deposited during it amount only to a thickness of about 3000 feet, and consequently are much inferior to the three first great groups. The three systems into which the tertiary period is subdivided are also very difficult to distinguish from one another. The oldest of them is called *eocene,* or old tertiary; the newer *miocene,* or mid tertiary; and the last is the *pliocene,* or later tertiary system.

The whole population of the tertiary epoch approaches much nearer, on the whole as well as in detail, to that of the present time than is the case in the preceding epochs. From here the class of *Mammals* greatly predominates over all other vertebrate animals. In like manner, in the vegetable kingdom, the group—so rich in forms—of the *Angiosperms,* or *plants with covered seeds,* predominates, and its *leafy forests* constitute the characteristic feature of the tertiary epoch. The group of the Angiosperms consists of the two classes of single-seed-lobed plants, or *Monocotyledons,* and the double-seed-lobed plants, or *Dicotyledons.* The Angiosperms of both classes had, it is true, made their appearance in the Cretaceous period, and mammals had already occurred in the Jurassic period, and even in the Triassic period; but both groups, the mammals and the plants with enclosed seeds, did not attain their peculiar development and supremacy until the tertiary epoch, so that it may justly be called after them.

The fifth and last main division of the organic history of the earth is the *quaternary epoch,* or *era of Civilization,* which in comparison with the length of the four other

epochs almost vanishes into nothing, though, with comical conceit, we usually call its record the "history of the world." As the period is characterized by the development of *Man* and his *Culture,* which has influenced the organic world more powerfully and with greater transforming effect than have all previous conditions, it may also be called the era of Man, the anthropolithic or anthropozoic period. It might also be called the era of Cultivated Forests, or Gardens, because even at the lowest stage of human civilization man's influence is already perceptible in the utilization of forests and their products, and therefore also in the physiognomy of the landscape. The commencement of this era, which extends down to the present time, is geologically bounded by the end of the pliocene stratification.

The neptunic strata which have been deposited during the comparatively short quaternary epoch are very different in different parts of the earth, but they are mostly of very slight thickness. They are reduced to two "systems," the older of which is designated the *diluvial,* or *pleistocene,* and the later the *alluvial,* or *recent.* The diluvial system is again divided into two "formations," the older *glacial* and the more recent *post glacial* formations. For during the older diluvial period there occurred that extremely remarkable decrease of the temperature of the earth which led to an extensive glaciation of the temperate zones. The great importance which this "ice" or "glacial period" has exercised on the geographical and topographical distribution of organisms has already been explained in a preceding chapter (vol. i. p. 380). But the *post glacial period,* or the more recent diluvial period, during which the temperature again increased and the ice retreated towards the poles,

was also highly important in regard to the present state of chorological relations.

The biological characteristic of the quaternary epoch lies essentially in the development and dispersion of the human organism and his culture. Man has acted with a greater transforming, destructive, and modifying influence upon the animal and vegetable population of the earth than any other organism. For this reason, and not because we assign to man a privileged exceptional position in nature in other matters, we may with full justice designate the development of man and his civilization as the beginning of a special and last main division of the organic history of the earth. It is probable indeed that the corporeal development of primæval man out of man-like apes took place as far back as the earlier pliocene period, perhaps even in the miocene tertiary period. But the actual development of *human speech*, which we look upon as the most powerful agency in the development of the peculiar characteristics of man and his dominion over other organisms, probably belongs to that period which on geological grounds is distinguished from the preceding pliocene period as the pleistocene or diluvial. In fact, the time which has elapsed from the development of human speech down to the present day, though it may comprise many thousands and perhaps hundreds of thousands of years, almost vanishes into nothing as compared with the immeasurable length of the periods which have passed from the beginning of organic life on the earth down to the origin of the human race.

The tabular view given on page 15 shows the succession of the palæontological rock-groups, systems, and formations, that is, the larger and smaller neptunic groups of strata,

which contain petrifactions, from the uppermost, or Alluvial, down to the lowest, or Laurentian, deposits. The table on page 14 presents the historical division of the corresponding eras of the larger and smaller palæontological periods, and in a reversed succession, from the most ancient Laurentian up to the most recent Quaternary period.

Many attempts have been made to make an approximate calculation of the number of thousands of years constituting these periods. The thickness of the strata has been compared, which, according to experience, is deposited during a century, and which amounts only to some few lines or inches, with the whole thickness of the stratified masses of rock, the succession of which we have just surveyed. This thickness, on the whole, may on an average amount to about 130,000 feet; of these 70,000 belong to the primordial, or archilithic; 42,000 to the primary, or palæolithic; 15,000 to the secondary, or mesolithic; and finally only 3000 to the tertiary, or cænolithic group. The very small and scarcely appreciable thickness of the quaternary, or anthropolithic deposit, cannot here come into consideration at all. On an average, it may at most be computed as from 500 to 700 feet. But it is self-evident that all these measurements have only an average and approximate value, and are meant to give only a rough survey of the *relative* proportion of the systems of strata and of the spaces of time corresponding with them.

Now, if we divide the whole period of the organic history of the earth—that is, from the beginning of life on the earth down to the present day—into a hundred equal parts, and if then, corresponding to the thickness of the systems of strata, we calculate the relative duration of the time of the

five main divisions or periods according to percentages, we obtain the following result:—

I.	Archilithic, or primordial period	53.6
II.	Palæolithic, or primary period	32.1
III.	Mesolithic, or secondary period	11.5
IV.	Cænolithic, or tertiary period	2.3
V.	Anthropolithic, or quaternary period	0.5
	Total ..	100.0

According to this, the length of the archilithic period, during which no land-living animals or plants as yet existed, amounts to more than one half, more than 53 per cent.; on the other hand, the length of the anthropolithic era, during which man has existed, amounts to scarcely one-half per cent. of the whole length of the organic history of the earth. It is, however, quite impossible to calculate the length of these periods, even approximately, by years.

The thickness of the strata of mud at present deposited during a century, and which has been used as a basis for this calculation, is of course quite different in different parts of the earth under the different conditions in which these deposits take place. It is very slight at the bottom of the deep sea, in the beds of broad rivers with a short course, and in inland seas which receive very scanty supplies of water. It is comparatively great on the sea-shores exposed to strong breakers, at the estuaries of large rivers with long courses, and in inland seas with copious supplies of water. At the mouth of the Mississippi, which carries with it a considerable amount of mud, in the course of 100,000 years about 600 feet would be deposited. At the bottom of the open sea, far away from the coasts, during this long period only some few feet of mud would be deposited. Even on the

sea-shores where a comparatively large quantity of mud is deposited, the thickness of the strata formed during the course of a century may after all amount to no more than a few inches or lines when condensed into solid stone. In any case, however, all calculations based upon these comparisons are very unsafe, and we cannot even approximately conceive the enormous length of the periods which were requisite for the formation of the systems of neptunic strata. Here we can apply only relative, not absolute, measurements of time.

Moreover, we should entirely err were we to consider the size of these systems of strata alone as the measure of the actual space of time which has elapsed during the earth's history. For the elevations and depressions of the earth's crust have perpetually alternated with one another, and the mineralogical and palæontological difference—which is perceived between each two succeeding systems of strata, and between each two of their formations at any particular spot—corresponds in all probability with a considerable intermediate space of many thousands of years, during which that particular part of the earth's crust was raised above the water. It was only after the lapse of this intermediate period, when a new depression again laid the part in question under water, that there occurred a new deposit of earth. As, in the mean time, the inorganic and organic conditions on this part had undergone a considerable transformation, the newly formed layer of mud was necessarily composed of different earthy constituents and enclosed different petrifactions.

The striking differences which so frequently occur between the petrifactions of two strata, lying one above

IV. Tertiary Group of Strata, 3000 feet.	Eocene, Miocene, Pliocene.
III. Mesolithic Group of Strata. Deposits of the Secondary Epoch, about 15,000 feet.	IX. Chalk System. .... VIII. Jura System. .... VII. Trias System.
II. Palæolithic Group of Strata. Deposits of the Primary Epoch, about 42,000 feet.	VI. Permian System. .... V. Coal System. .... IV. Devonian System.
I. Archilithic Group of Strata. Deposits of the Primordial Epoch, about 70,000 feet.	III. Silurian System, about 22,000 feet. .... II. Cambrian System, about 18,000 feet. .... I. Laurentian System, about 30,000 feet.

another, are to be explained in a simple and easy manner by the supposition that the same part of the earth's surface has been exposed to *repeated depressions and elevations.* Such alternating elevations and depressions take place even now extensively, and are ascribed to the heaving of the fiery fluid nucleus against the rigid crust. Thus, for example, the coast of Sweden and a portion of the west coast of South America are constantly though slowly rising, while the coast of Holland and a portion of the east coast of South America are gradually sinking. The rising as well as the sinking takes place very slowly, and in the course of a century sometimes only amounts to some few lines, sometimes to a few inches, or at most a few feet. But if this action continues uninterruptedly throughout hundreds of thousands of years, it is capable of forming the highest mountains.

It is evident that elevations and depressions, such as now can be measured in these places, have uninterruptedly alternated one with another in different places during the whole course of the organic history of the earth. This may be inferred with certainty from the geographical distribution of organisms. But to form a judgment of our palæontological records of creation it is extremely important to show that permanent strata can only be deposited during a slow sinking of the ground under water, but not during its continued rising. When the ground slowly sinks more and more below the level of the sea, the deposited layers of mud get into continually deeper and quieter water, where they can become condensed into stone undisturbed. But when, on the other hand, the ground slowly rises, the newly deposited layers of mud,

which enclose the remains of plants and animals, again immediately come within the reach of the play of the waves, and are soon worn away by the force of the breakers, together with the organic remains which they enclose. For this simple but very important reason, therefore, abundant layers, in which organic remains are preserved, can only be deposited during a continuous sinking of the ground. When any two different formations or strata, lying one above the other, correspond with two different periods of depression, we must assume a long period of rising between them, of which period we know nothing, because no fossil remains of the then living animals and plants could be preserved. It is evident, however, that these *periods of elevation,* which have passed without leaving any trace behind them, deserve a no less careful consideration than the greater or less alternating *periods of depression,* of whose organic population we can form an approximate idea from the strata containing petrifactions. Probably the former were not of shorter duration than the latter.

From this alone it is apparent how imperfect our records must necessarily be, and all the more so since it can be theoretically proved that the variety of animal and vegetable life must have increased greatly during those very periods of elevation. For as new tracts of land are raised above the water, new islands are formed. Every new island, however, is a new centre of creation, because the animals and plants accidentally cast ashore there, find in the new territory, in the struggle for life, abundant opportunity of developing themselves peculiarly, and of forming new species. This formation of new species has evidently taken place pre-eminently during these intermediate periods,

of which, unfortunately, no petrifactions could be preserved, whereas, on the contrary, during the slow sinking of the ground there was more chance of numerous species dying out, and of a retrogression into fewer specific forms. The intermediate forms between the old and the newly forming species must also have lived during the periods of elevation, and consequently could likewise leave no fossil remains.

In addition to the great and deplorable gaps in the palæontological records of creation—which are caused by the periods of elevation—there are, unfortunately, many other circumstances which immensely diminish their value. I must mention here especially the *metamorphic state of the most ancient formations*, of those strata which contain the remains of the most ancient flora and fauna, the original forms of all subsequent organisms, and which, therefore, would be of especial interest. It is just these rocks—and, indeed, the greater part of the primordial, or archilithic strata, almost the whole of the Laurentian, and a large part of the Cambrian systems—which no longer contain any recognizable remains, and for the simple reason that these strata have been subsequently changed or metamorphosed by the influence of the fiery fluid interior of the earth. These deepest neptunic strata of the crust have been completely changed from their original condition by the heat of the glowing nucleus of the earth, and have assumed a crystalline state. In this process, however, the form of the organic remains enclosed in them has been entirely destroyed. It has been preserved only here and there by a happy chance, as in the case of the most ancient petrifactions, the lowest Cambrian and Laurentian strata. How-

ever, from the layers of crystalline charcoal (graphite) and crystalline limestone (marble) which are found deposited in the metamorphic rocks, we may with certainty conclude that petrified animal and vegetable remains existed in them in earlier times.

Our record of creation is also extremely imperfect from the circumstance that only a small portion of the earth's surface has been accurately investigated by geologists—Europe and North America more especially. Certain tracts in South America and in the East Indies have been investigated, but the greater part is not known. This applies also to the larger portion of Asia, the most extensive of all continents. Of Africa almost nothing is known, excepting the Cape of Good Hope and the shores of the Mediterranean; of Australia we know but very little. It is clear, therefore, that only quite a small portion, perhaps scarcely the thousandth part of the whole surface of the earth, has been palæontologically investigated. We may therefore reasonably hope, when more extensive geological investigations are made, which are greatly assisted by the constructions of railroads and mines, to find a great number of other important petrifactions. A hint that this will be the case is given by the remarkable petrifactions found in those parts of Africa and Asia which have been minutely investigated,—the Cape districts and the Himalaya Mountains. A series of entirely new and very peculiar animal forms have become known to us from the rocks of these localities. But we must bear in mind that the vast bottom of the existing oceans is at the present time quite inaccessible to palæontological investigations, and that the greater part of the petrifactions which have lain there from primæval times

will either never be known to us, or at best only after the course of many thousands of years, when the present bottom of the ocean shall have become accessible by gradual elevation. If we call to mind the fact that three-fifths of the whole surface of the earth consists of water, and only two-fifths of land, it becomes plain that on this account the palæontological record must always present an immense gap.

But, in addition to these, there exists another series of difficulties in the way of palæontology which arises from the nature of the organisms themselves. In the first place, as a rule only the hard and solid parts of organisms can fall to the bottom of the sea or of fresh waters, and be there enclosed in the mud and petrified. Hence it is only the bones and teeth of vertebrate animals, the calcareous shells of molluscs, the chitinous skeletons of articulated animals, the calcareous skeletons of star-fishes and corals, and the woody and solid parts of plants, that are capable of being petrified. But soft and delicate parts, which constitute by far the greater portion of the bodies of most organisms, are very rarely deposited in the mud under circumstances favourable to their becoming petrified, or distinctly impressing their external form upon the hardening mud. Now, it must be borne in mind that large classes of organisms, as for example the Medusæ, the naked molluscs without shells, a large portion of the articulated animals, almost all worms, and even the lowest vertebrate animals, possess no firm and hard parts capable of being petrified. In like manner, the most important parts of plants, such as the flowers, are for the most part so soft and tender that they cannot be preserved in a recognizable form. We therefore cannot expect

to find any petrified remains of these important organisms. Moreover, all organisms at an early stage of life are so soft and tender that they are quite incapable of being petrified. Consequently all the petrifactions found in the neptunic stratifications of the earth's crust comprise altogether but a very few forms, and of these for the most part only isolated fragments.

We must next bear in mind that the dead bodies of the inhabitants of the sea are much more likely to be preserved and petrified in the deposits of mud than those of the inhabitants of fresh water and of the land. Organisms living on land can, as a rule, become petrified only when their corpses fall accidentally into the water and are buried at the bottom in the hardening layers of mud. But this event depends upon very many conditions. We cannot therefore be astonished that by far the majority of petrifactions belong to organisms which have lived in the sea, and that of the inhabitants of the land proportionately only very few are preserved in a fossil state. How many contingencies come into play here we may infer from the single fact that of many fossil mammals, in fact of all the mammals of the secondary, or mesozoic epoch, nothing is known except the lower jawbone. This bone is in the first place comparatively solid, and in the second place very easily separates itself from the dead body, which floats on the water. Whilst the body is driven away and dissolved by the water, the lower jawbone falls down to the bottom of the water and is there enclosed in the mud. This explains the remarkable fact that in a stratum of limestone of the Jurassic system near Oxford, in the slates of Stonesfield, as yet only the lower jawbones of numerous pouched animals (Marsupials)

have been found. They are the most ancient mammals known, and of the whole of the rest of their bodies not a single bone exists. The opponents of the theory of development, according to their usual logic, would from this fact be obliged to draw the conclusion that the lower jawbone was the only bone in the body of those animals.

Footprints are very instructive when we attempt to estimate the many accidents which so arbitrarily influence our knowledge of fossils; they are found in great numbers in different extensive layers of sandstone; for example, in the red sandstone of Connecticut, in North America. These footprints were evidently made by vertebrate animals, probably by reptiles, of whose bodies not the slightest trace has been preserved. The impressions which their feet have left on the mud alone betray the former existence of these otherwise unknown animals.

The accidents which, besides these, determine the limits of our palæontological knowledge, may be inferred from the fact that we know of only one or two specimens of very many important petrifactions. It is only about thirty years ago that we became acquainted with the imperfect impression of a bird in the Jurassic or Oolitic system, the knowledge of which has been of the very greatest importance for the phylogeny of the whole class of birds. All birds previously known presented a very uniformly organized group, and showed no striking transitional forms to other vertebrate classes, not even to the nearly related reptiles. But that fossil bird (Archæopteryx) from the Jura possessed not an ordinary bird's tail, but a lizard's tail, and thus confirmed what had been conjectured upon other grounds, namely, the derivation of birds from lizards. This single fossil has thus

essentially extended not only our knowledge of the age of the class of birds, but also of their blood-relationship to reptiles. In like manner our knowledge of other animal groups has been often essentially modified by the accidental discovery of a single fossil. The palæontological records must necessarily be exceedingly imperfect, because we know of so very few examples, or only mere fragments of very many important fossils.

Another and very sensible gap in these records is caused by the circumstance that the *intermediate forms* which connect the different species have, as a rule, not been preserved, and for the simple reason that (according to the principle of divergence of character) they were less favoured in the struggle for life than the most divergent varieties, which had developed out of one and the same original form. The intermediate links have, on the whole, always died out *rapidly*, and have but rarely been preserved as fossils. On the other hand, the most divergent forms were able to maintain themselves in life for a longer period as independent species, to propagate more numerously, and consequently to be more readily petrified. But this does not exclude the fact that in *some* cases the connecting intermediate forms of the species have been preserved so perfectly petrified, that even now they cause the greatest perplexity and occasion endless disputes among systematic palæontologists about the arbitrary limits of species.

An excellent example of this is furnished by the celebrated and very variable fresh-water snail from the Stuben Valley, near Steinheim, in Würtemburg, which has been described sometimes as *Paludina*, sometimes as *Vavata*, and sometimes as *Planorbis multiformis*. The snow-white shells of

these small snails constitute more than half of the mass of the tertiary limestone hills, and in this one locality show such an astonishing variety of forms, that the most divergent extremes might be referred to at least twenty entirely different species. But all these extreme forms are united by such innumerable intermediate forms, and they lie so regularly above and beside one another, that Hilgendorf was able, in the clearest manner, to unravel the pedigree of the whole group of forms. In like manner, among very many other fossil species (for example, many ammonites, terebratulæ, sea-urchins, lily encrinites, etc.) there are such masses of connecting intermediate forms, that they reduce the "dealers in fossil species" to despair.

When we weigh all the circumstances here mentioned, the number of which might easily be increased, it does not appear astonishing that the natural accounts or records of creation formed by petrifactions are extremely defective and incomplete. But nevertheless, the petrifactions actually discovered are of the greatest value. Their significance is of no less importance to the natural history of creation than the celebrated inscription on the Rosetta Stone, and the decree of Canopus, are to the history of nations—to archæology and philology. Just as it has become possible by means of these two most ancient inscriptions to reconstruct the history of ancient Egypt, and to decipher all hieroglyphic writings, so in many cases a few bones of an animal, or imperfect impressions of a lower animal or vegetable form, are sufficient for us to gain the most important starting-points in the history of the whole group, and in the search after their pedigree. A couple of small back teeth, which have been found in the Keuper formation

of the Trias, have of themselves alone furnished a sure proof that mammals existed even in the Triassic period.

Of the incompleteness of the geological accounts of creation, Darwin, agreeing with Lyell, the greatest of all recent geologists, says—

"I look at the geological record as a history of the world imperfectly kept, and written in a changing dialect; of this history we possess the last volume alone, relating only to two or three countries. Of this volume, only here and there a short chapter has been preserved; and of each page, only here and there a few lines. Each word of the slowly changing language, more or less different in the successive chapters, may represent the forms of life which are entombed in our consecutive formations, and which falsely appear to us to have been abruptly introduced. On this view, the difficulties above discussed are greatly diminished, or even disappear."—*Origin of Species,* 6th Edition, p. 289.

If we bear in mind the exceeding incompleteness of palæontological records, we shall not be surprised that we are still dependent upon so many uncertain hypotheses when actually endeavouring to sketch the pedigree of the different organic groups. However, we fortunately possess, besides fossils, other records of the history of the origin of organisms, which in many cases are of no less value, nay, in several cases are of much greater value, than fossils. By far the most important of these other records of creation is, without doubt, *ontogeny,* that is, the history of the development of the organic individual (embryology and metamorphology). It briefly repeats in clear and marked outlines the history of the tribe, or their phylogeny.

It is true that the sketch which the ontogeny of organisms gives us of their phylogeny is in most cases more or less obscured, and all the more so, the more that Adaptation, in the course of time, has predominated over Inheritance, and the more powerfully the law of abbreviated inheritance, and the law of correlative adaptation, have exerted their influence. However, this does not lessen the great value which the actual and faithfully preserved features of that sketch possess. *Ontogeny is of the most inestimable value for the knowledge of the earliest palæontological conditions of development,* just because no petrified remains of the most ancient conditions of the development of tribes and classes have been preserved. These, indeed, could not have been preserved on account of the soft and tender nature of their bodies. No petrifactions could inform us of the fundamental and important fact which ontogeny reveals to us, that the most ancient common ancestors of all the different animal and vegetable species were quite simple cells like the egg-cell. No petrifaction could prove to us the immensely important fact, established by ontogeny, that the simple increase, the formation of cell-aggregates and the differentiation of those cells, produced the infinitely manifold forms of multicellular organisms. Thus ontogeny helps us over many and large gaps in palæontology.

To the invaluable records of creation furnished by palæontology and ontogeny are added the no less important evidences for the blood-relationship of organisms furnished by *comparative anatomy.* When organisms, externally very different, nearly agree in their internal structure, one may with certainty conclude that the agreement has its

foundation in Inheritance, the dissimilarity its foundation in Adaptation. Compare, for example, the hands and fore paws of the nine different animals which are represented on Plate IV., in which the bony skeleton in the interior of the hand and of the five fingers is visible. Everywhere we find, though the external forms are most different, the same bones, and among them the same number, position, and connection. It will perhaps appear very natural that the hand of *man* (Fig. 1) differs very little from that of the *gorilla* (Fig. 2) and of the *orang-outang* (Fig. 3), his nearest relations. But it will be more surprising if the fore feet of the *dog* also (Fig. 4), as well as the breast-fin (the hand) of the *seal* (Fig. 5), and of the *dolphin* (Fig. 6), show essentially the same structure. And it will appear still more wonderful that even the wing of the *bat* (Fig. 7), the shovel-feet of the *mole* (Fig. 8), and the fore feet of the *duck-bill* (Ornithorhynchus) (Fig. 9), the most imperfect of all mammals, are composed of entirely the same bones, only their size and form being variously changed. Their number, the manner of their arrangement and connection, has remained the same. (Compare also the explanation of Plate IV., in the Appendix.) It is quite inconceivable that any other cause, except the common inheritance of the part in question from common ancestors, could have occasioned this wonderful homology or similarity in the essential inner structure with such different external forms. Now, if we go down further in the system below the mammals, and find that even the wings of birds, the fore feet of reptiles and amphibious animals, are composed of essentially the same bones as the arms of man and the fore legs of the other

mammals, we can, from this circumstance alone, with perfect certainty, infer the common origin of all these vertebrate animals. Here, as in all other cases, the degree of the internal agreement in the form discloses to us the degree of blood-relationship.

CHAPTER XVII.

PHYLOGENETIC SYSTEM OF ORGANISMS: PROTISTA AND HISTONS.

Special Mode of carrying out the Theory of Descent in the Natural System of Organisms.—Construction of Pedigrees.—Descent of all Many-celled from Single-celled Organisms.—Descent of Cells from Monera.—Meaning of Organic Tribes, or Phyla.—Number of the Tribes in the Animal and Vegetable Kingdoms.—The Monophyletic Hypothesis of Descent, or the Hypothesis of one Common Progenitor, and the Polyphyletic Hypothesis of Descent, or the Hypothesis of Many Progenitors.—The Kingdom of Protista (One-celled Organisms).—Contrast to the Kingdom of Histons (Many-celled Animals and Plants).—Boundary between the Animals and Vegetable Kingdoms.—Primary Plants (Protophyta) and Primary Animals (Protozoa).—Monobia and Cœnobia.—Results of the *Challenger* Expedition.—History of the Radiolaria.—System of the Organic Kingdom.

By a careful comparison of the individual and the palæontological development, as also by the comparative anatomy of organisms, by the comparative examination of their fully developed structural characteristics, we arrive at the knowledge of the degrees of their different structural relationships. By this, however, we at the same time obtain an insight into their true *blood-relationship*, which, according to the Theory of Descent, is the real reason of the structural relationship. Hence by collecting, comparing, and employing the empirical results of embryology, palæon-

tology, and anatomy for supplementing each other, we arrive at an approximate knowledge of "the Natural System," which, according to our views, is the *pedigree* of organisms. It is true that our human knowledge, in all things fragmentary, is especially so in this case, on account of the extreme incompleteness and defectiveness of the records of creation. However, we must not allow this to discourage us, or to deter us from undertaking this highest problem of biology. Let us rather see how far it may even now be possible, in spite of the imperfect state of our embryological, palæontological, and anatomical knowledge, to establish a probable scheme of the genealogical relationships of organisms.

Darwin in his book gives us no answer to these special questions of the Theory of Descent; at the conclusion he only expresses his conjecture "that animals have descended from at most only four or five progenitors, and plants from an equal or less number." But as these few aboriginal forms still show traces of relationship, and as the animal and vegetable kingdoms are connected by intermediate transitional forms, he arrives afterwards at the opinion "that probably all the organic beings which have ever lived on the earth have descended from some one primordial form."

In 1866 I set up a number of hypothetical genealogies for the larger groups of organisms in the systematic introduction to my "General History of Development," and thereby, in fact, made the first attempt actually to construct the pedigrees of organisms in the manner required by the theory of development. I was quite conscious of the extreme difficulty of the task, and as I undertook it in spite of all

discouraging obstacles, I claim no more than the merit of having made the first attempt and given a stimulus for other and better attempts. Most zoologists and botanists were but little satisfied with this beginning, and least so in reference to the special domain in which each one is specially at work. However, it is certainly in this case much easier to blame than to produce anything better.

During the twenty-three years which have passed since the publication of my "General Morphology," very much has been done towards filling in the phylogeny which I had there given only in outline. And, indeed, many raised their voices against it at first, not only to proclaim my first sketches as absolute failures, but to maintain that phylogenetic investigations generally, and the construction of hypothetical pedigrees based upon it, was an unscientific procedure, and, in fact, an impossibility. Du Bois Raymond tried to make them appear ridiculous by comparing them with philological investigations on the pedigrees of the Homeric heroes. But the joy of our opponents, over these and similar attacks, especially by physiologists, was of short duration; for soon, and in the pleasantest way, phylogenetic inquiry was found to be active in all directions. Every thinking morphologist, at work in classifying any of the larger or smaller groups of the animal kingdom, was necessarily led to the question of their blood-relationship by a knowledge of their form-relationship; and in many cases the outlines presented themselves so clearly that the investigator could obtain a perfect idea of the origin and of the gradual development of the group of animals; thus, for instance, in the case of Hoofed animals, Sharks, the Crustacea, Ammonites, Sea-urchins, Sea-lilies, etc. I have

myself, in my monographs on the Radiolaria, Calcareous Sponges, Medusæ, and the Siphonophora, endeavoured to show how far it is possible to establish the pedigree of this group of animals, so rich in forms, on the basis of known records. Like all other scientific hypotheses which serve to explain facts, my genealogical hypotheses may claim to be taken into consideration until they are replaced by better ones.

I hope that this replacement will very soon take place; and I wish for nothing more than that my first attempt may induce very many naturalists to establish more accurate pedigrees for the individual groups, at least in the special domain of the animal and vegetable kingdom which happens to be well known to one or other of them. By numerous attempts of this kind our genealogical knowledge, in the course of time, will slowly advance and approach more and more towards perfection, although it can with certainty be foreseen that we shall never arrive at a complete pedigree. We lack, and shall ever lack, the indispensable palæontological foundations. The most ancient records will ever remain sealed to us, for reasons which have been previously mentioned. The most ancient organisms which arose by spontaneous generation—the original parents of all subsequent organisms—must necessarily be supposed to have been Monera—simple, soft, albuminous lumps of plasma, without structure, without any definite form, and entirely without any hard and formed parts. They and their next offspring were consequently not in any way capable of being preserved in a petrified condition. But we also lack, for reasons discussed in detail in the preceding chapter, by far the greater portion of the in-

numerable palæontological documents, which are really requisite for a safe reconstruction of the history of animal tribes, or phylogeny, and for the true knowledge of the pedigree of organisms. If we, therefore, in spite of this, venture to undertake their hypothetical construction, we must chiefly depend for guidance on the two other series of records which most essentially supplement the palæontological archives. These are ontogeny and comparative anatomy.

If thoughtfully and carefully we consult these most valuable records, we at once perceive what is exceedingly significant, namely, that the lowest and simplest forms of life, the so-called primary plants and primary animals, consist throughout life merely of one simple cell; they are permanently one-celled. On the other hand, that most organisms, especially all the higher animals and plants, are many-celled, are formed of a great number of closely connected cells; and that they originate out of an egg, and that this egg, in animals as well as in plants, is a single, perfectly simple cell—a little lump of albuminous constitution, in which another albuminous corpuscle, the cell-kernel, is enclosed. This cell containing its kernel grows and becomes enlarged. By division it forms an accumulation of cells, and out of these, by division of labour (as has previously been described), there arise the numberless different forms which are presented to us in the fully developed animal and vegetable species. This immensely important process—which we may follow step by step, with our own eyes, any day in the embryological development of any animal or vegetable individual, and which as a rule is by no means considered with the reverence

it deserves—informs us more surely and completely than all petrifactions could do as to the original palæontological development of all many-celled organisms, that is, of all higher animals and plants. For as ontogeny, or the embryological development of every single individual, is essentially only a recapitulation of phylogeny, or the palæontological development of its chain of ancestors, we may at once, with full assurance, draw the simple and important conclusion, that *all many-celled animals and plants were originally derived from single-celled organisms.*

The primæval ancestors of man, as well as of all other animals, and of all plants composed of many cells, were simple cells living isolated. This invaluable secret of the organic pedigree is revealed to us with infallible certainty by the egg-cell of animals and of plants. When the opponents of the Theory of Descent assert it to be miraculous and inconceivable that an exceedingly complicated many-celled organism could, in the course of time, have proceeded from a simple single-celled organism, we at once reply that we may see this incredible miracle at any moment, and follow it with our own eyes. For the embryology of animals and plants visibly presents to our eyes in the shortest space of time the same process as that which has taken place in the origin of the whole tribe during the course of enormous periods of time.

Upon the ground of embryological records, therefore, we can with full assurance maintain that all many-celled, as well as single-celled, organisms are originally descended from simple cells; connected with this, of course, is the conclusion that the most ancient root of the animal and vegetable kingdom was common to both, *a most simple cell.*

For the different primæval "original cells" out of which the few different main groups or tribes have developed, only acquired their differences after a time, and were descended from a common "primæval cell." But where did those few "original cells," or the one primæval cell, come from? For the answer to this fundamental genealogical question we must return to the theory of plastids and the hypothesis of spontaneous generation which we have already discussed (vol. i. p. 401).

As was then shown, we cannot imagine *cells* to have arisen by spontaneous generation, but only *Monera*, those primæval creatures of the simplest kind conceivable, like the still living Protamœbæ, Protomyxæ, etc. Only such corpuscles of mucus without component parts—whose whole albuminous body is as homogeneous in itself as an inorganic crystal, but which nevertheless fulfils the two organic fundamental functions of nutrition and propagation —could have directly arisen out of inorganic matter by autogeny at the beginning (we may suppose) of the Laurentian period. While some Monera remained at the original simple stage of formation, others gradually developed into cells by the inner kernel of the mass of plasma becoming separated from the external cell-substance. In others, by differentiation of the outermost layer of the cell-substance, an external covering (membrane, or skin) was formed round simple cytods (without kernel), as well as round naked cells (containing a kernel). By these two processes of separation in the simple primæval mucus of the Moneron body, by the formation of a kernel in the interior and a covering on the outer surface of the mass of plasma, there arose out of the original most simple cytods, the Monera,

those four different species of plastids, or individuals of the first order, from which, by differentiation and combination, all other organisms could afterwards develop themselves. (Compare vol. i. p. 405.) At all events, the Monera are the primary sources of all life.

The question now forces itself upon us, Are all organic cytods and cells, and consequently also those "original cells" which we previously considered to be the primary parents of the few great main groups of the animal and vegetable kingdoms, descended from a single original form of Moneron, or were there several different organic primary forms, each traceable to a peculiar independent species of Moneron which originated by spontaneous generation? In other words, *Is the whole organic world of a common origin, or does it owe its origin to several acts of spontaneous generation?* This fundamental question of genealogy seems at first sight to be of exceeding importance. But, on a more accurate examination, we shall soon see that this is not the case, and that it is in reality a matter of very subordinate importance.

Let us now pass on to examine and clearly limit our conception of an *organic tribe.* By *tribe,* or *phylum,* we understand all those organisms of whose blood-relationship and descent from a common primary form there can be no doubt, or whose relationship, at least, is most probable from anatomical reasons, as well as from reasons founded on historical development. Our tribes, or phyla, according to this idea, essentially coincide with those few "great classes," or "main classes," of which Darwin also thinks that each contains only organisms related by blood, and of which, both in the animal and in the vegetable kingdoms, he only

assumes either four or five. In the animal kingdom these tribes would essentially coincide with those four, five, or six main divisions which zoologists, since Bär and Cuvier, have distinguished as "main forms, general plans, branches, or sub-kingdoms" of the animal kingdom. (Compare vol. i. p. 54.) Bär and Cuvier distinguished only four of them, namely:—1. The vertebrate animals (Vertebrata); 2. The articulated animals (Articulata); 3. The molluscous animals (Mollusca); and 4. The radiated animals (Radiata). At present eight are generally distinguished, for while the first three main classes or sub-kingdoms are retained, the fourth (the Radiata) is divided into five branches; these are the tunicated animals (Tunicata), star animals (Echinoderma), worm animals (Helminthes), plant animals (Zoophyta), and primary animals (Protozoa). Within each of these eight tribes, all the included animals, in spite of great variety in external form and inner structure, nevertheless possess such numerous and important characteristics in common, that there can be no doubt of their blood-relationship.

The same applies also to the six great main classes which modern botany distinguishes in the vegetable kingdom, namely:—1. Flowering plants (Phanerogamia); 2. Ferns (Filicinæ); 3. Mosses (Muscinæ); 4. Lichens (Lichenes); 5. Fungi (Fungi); and 6. Water-weeds (Algæ). The last three groups, again, show such close relation to one another, that by the name of Thallus plants (Thallophyta) they may be contrasted with the three first main classes, and consequently the number of phyla, or main groups, of the vegetable kingdom may be reduced to the number of four. Mosses and ferns may likewise be comprised as "Prothallus plants" (Prothallota), and thereby the number of plant

tribes reduced to three—Flowering plants, Prothallus plants, and Thallus plants. But we must at once expressly remark, with regard to this classification, that the morphological and phylogenetic relations of the six tribes of the vegetable kingdom are wholly different from those of the eight tribes of the animal kingdom.

Very important facts in the anatomy and the history of development, both in the animal and vegetable kingdoms, support the supposition that even these few main classes or tribes are connected at their roots, that is, that the lowest and most ancient primary forms of all three are related by blood to one another. We shall subsequently see in what a different manner this phylogenetic connection has to be conceived, on the one hand for the tribes of the animal kingdom, on the other for the vegetable kingdom. Nay, we might even go a step further, and assume, with Darwin, that even the two pedigrees of the animal and vegetable kingdom are connected at their lowest roots, and that the lowest and most ancient animals and plants are derived from a single common primary creature. Of course, in our opinion this common primæval organism can have been nothing but a most simple Moneron which took its origin by spontaneous generation.

In the mean time we shall at all events be acting cautiously if we avoid this last step, and assume true blood-relationship only within each tribe, or phylum, where it has been undeniably and surely established by facts in comparative anatomy, ontogeny, and palæontology. But we may here point to the fact that two different fundamental forms of genealogical hypothesis are possible, and that all the different investigations of the Theory of Descent in

relation to the origin of organic groups of forms will, in future, tend more and more in one or the other of these directions. The unitary, or *monophyletic*, hypothesis of descent will endeavour to trace the first origin of all individual groups of organisms, as well as their totality, to a single common species of Moneron which originated by spontaneous generation. The multiple, or *polyphyletic*, hypothesis of descent, on the other hand, will assume that several different species of Monera have arisen by spontaneous generation, and that these gave rise to several different main classes (tribes, or phyla). The apparently great contrast between these two hypotheses is in reality of very little importance. For both the monophyletic and the polyphyletic hypothesis of descent must necessarily go back to the Monera as the most ancient root of the one or of the many organic tribes. But as the whole body of a Moneron consists only of a simple, formless mass of plasson, without component particles, made up of a single albuminous combination of carbon, it follows that the differences of the different Monera can only be of a chemical nature, and can only consist in a different atomic composition of that mucous albuminous combination. But these subtle and complicated differences of mixture of the infinitely manifold combinations of albumen are not appreciable by the rude and imperfect means of human observation, and are, consequently, at present of no further interest to the task we have in hand.

The question of the monophyletic or polyphyletic origin will constantly recur within each individual tribe, where the origin of a smaller or of a larger group is discussed. In the vegetable kingdom, for example, some botanists will be inclined to derive all flowering plants from a single form

of fern, while others will prefer the idea that several different groups of Phanerogama have sprung from several different groups of ferns. In like manner, in the animal kingdom, some zoologists will be more in favour of the supposition that all placental animals are derived from a single pouched animal; others will be more in favour of the opposite supposition, that several different groups of placental animals have proceeded from several different pouched animals. In regard to the human race itself, some will prefer to derive it from a single form of ape, while others will be more inclined to the idea that several different races of men have arisen, independently of one another, out of several different species of ape. Without here expressing our opinion in favour of either the one or the other conception, we must, nevertheless, remark that in general *the monophyletic hypothesis of descent* possesses more internal probability *for the highest and higher groups of forms, whereas the polyphyletic hypothesis* appears more probable *for the lower and lowest subdivisions.* And this applies to the animal world as well as to the vegetable kingdom. In accordance with the chorological proposition of a single "centre of creation" or of a single primæval home for most species (which has already been discussed), we may be permitted to assume that the original form of every larger or smaller natural group only originated *once* in the course of time, and only in *one part* of the earth. We may safely assume this simple original root, that is, the monophyletic origin, in the case of all the more highly developed groups of the animal and vegetable kingdoms. But this does not apply to the simple organisms of the lowest rank. It seems probable that the more complete

Theory of Descent of the future will maintain the polyphyletic origin for both organic kingdoms. (See my Essay on "Monophyletic and Polyphyletic Origin" in *Kosmos*, vol. iv., 1879.) On the other hand, again, many facts speak for an original connection of all the earliest primary roots. We may, accordingly, meanwhile, at all events (as an ingenious hypothesis!), assume a monophyletic origin for the animal kingdom on the one hand, and for the vegetable kingdom on the other.

In order to be able correctly to judge of these difficult questions in phylogeny, and to approach the solution of them with certainty, we must first of all bear in mind one important consideration, namely, the essential difference between the development of the one-celled and the many-celled organisms. This difference has hitherto not been sufficiently taken into account, although it is of the greatest importance, both in a morphological as well as in a physiological respect. For the relation between the permanent one-celled organism and the more highly developed many-celled individual is precisely the same as that of the single human person and the social community. It is only by means of the intimate connection between the many cells and the whole organism—their division of labour and separation of forms—that renders possible that higher manifestation of vital activities and of forms which we admire in the many-celled animals and plants. In the one-celled forms of life these are not met with; they remain always at a much lower stage.

For these and other reasons I propose, as I have already on a previous occasion, to divide the whole living organic world into two main groups: the Protista and the Histons. The

Protista, or *one-celled organisms,* either retain throughout life their full independence as simple cells (Eremobia), or they form, by association, mere loosely connected cell-heaps (Cœnobia), but never actual tissue. The *Histons,* or *many-celled organisms,* on the other hand, are one-celled only at the beginning of their existence; by repeated division of the primary cell there soon arise organized communities of cells, and out of these, tissues (hista). The simplest form of tissue is met with in the plants of the Thallus group, in animals in the germinal skin or membrane, the blastoderm.

From these facts of the comparative history of development we may with perfect assurance infer that all Histons were originally derived from Protista; all many-celled animals, as well as all many-celled plants must, of course, have originated out of single-celled ancestors, for even at present every single many-celled organism develops actually out of a single-celled germ (Cytula, see vol. i. p. 342). This "progeny cell," according to the fundamental law of biogeny, is the hereditary repetition of the "primary cell," of the original historical ancestral form, or of the one-celled ancestor. But from this it by no means follows that all the Protista known to us are ancestors of the Histons; on the contrary, only a very small portion of the former can be admitted into the pedigree of the latter. The large majority of all Protista have independent roots, which stand in no direct phylogenetic relation either to the vegetable or to the animal kingdom.

The extensive microscopic investigations of the last half-century have revealed to us a marvellous world of so-called "invisible life." Our improved microscopes have introduced us to thousands of species of the minutest creatures which

were hidden from the naked eye, and yet are of the utmost interest, owing to the great variety of their graceful forms, as well as of their simple vital phenomena. The first detailed account of them was given in 1838 by the celebrated Berlin microscopist, Gottfried Ehrenberg, in his great work, "The Infusoria as Perfect Organisms" ("Die Infusions-Thierchen als vollkommene Organismen"). This work gives a description and drawings of numerous microscopic organisms of the most different classes, and of entirely unequal organization. Ehrenberg, by means of his investigations, arrived at the wrong conclusion—that their body in general possessed a very perfect construction of different organs, similar to that of the higher animals; upon this error he based his peculiar principle of a perfect organization everywhere. But this, in fact, does not exist; and the majority of his so-called infusoria are single-celled Protista.

In the same year, 1838, when Ehrenberg published his great work on the Infusoria, Schwann established his cell-theory, and Ehrenberg, up to the end of his life, in 1876, was his most vehement opponent in this. The greatest gain obtained from the theory of cells was, first of all, the knowledge that all the different tissues of animal and vegetable bodies were composed of one and the same form-element, a simple cell. The stalk and leaves, the flowers and fruits of plants, as well as the nerves and muscles, the covering and connecting tissues of animals, are accumulations of milliards of microscopic cells; their different construction is purely the result of the different order and arrangement, the division of labour and separation of forms of the constituent cells. In the simpler tissues of plants, these

cells, as the building material of the tissues, show greater independence, and are usually covered by a firm skin or membrane; this is wanting in most cells of the animal tissue which attains a higher development.

Numerous microscopic living forms which Ehrenberg had described as highly organized Infusoria were shortly afterwards recognized as simple, independent living cells; and in 1848 Siebold proved this even as regards the fringed animalcules (Ciliata) and the ray-streamers (Rhizopoda), which had been generally considered as highly organized creatures; he established for them the special main-class of one-celled primæval animals (*Protozoa*). However, it was some time before this important fact became universally accepted. It was not until our knowledge of cell-life had been further worked out, and till, in 1872, I classed the genuine many-celled animalcules as *Metazoa*, in contrast to the one-celled *Protozoa*, that the fundamental difference between the two realms was generally recognized.

The many endeavours made to solve these difficult and important questions resulted in the publication of a great number of interesting treatises some thirty years ago—shortly before and after the appearance of Darwin's chief work (1859). In these treatises, zoologists and botanists, anatomists and physiologists, embryologists and systematists, all endeavoured to establish some definite boundary between the animal and the vegetable kingdoms. But however easy and certain this boundary may appear upon a comparison of the higher animals and plants, the greater seems the difficulty, nay, the impossibility, to do so in the case of the lower and imperfect organisms. All the structural characteristics and the vital phenomena which so strikingly

distinguish the higher and perfect animals and plants, seem effaced or mingled in many of the lower and simple creatures. And, moreover, many one-celled organisms present such an indifferent character or such a mixture of animal and vegetable peculiarities, that it appears inconsistent to place them either in the animal or in the vegetable kingdom.

Owing to these considerations, and also to the recognized inability of naturalists to determine the boundary between the two kingdoms, in 1866 I made an endeavour, in my "General Morphology," to solve the question in a different way. The second book of this work contains detailed "general investigations on the nature and first origin of organisms, their relation to the anorgana, and their division into animals and plants" (vol. i. pp. 111–238.) I there proposed to establish a special "kingdom of Protista" for all such lower forms of life as cannot be regarded either as genuine animals or as genuine plants. An essential characteristic of the Protista kingdom I held to be the generally *permanent independence of the plastids,* the individuals of the first order (cells or cytods), and, further, the *absence* of tissue which resulted from this. The whole developed organization of the Protista usually consists merely of a single plastid or Monobia (at times a non-kernelled cytod, at times a kernelled cell); more rarely do we find that these have arisen by repeated division of the cells, and a loose connection between the part-products, so-called cell-heaps or Cœnobia (also called cell colonies or communities of plastids). But never do they develop into those firm bands of cells which are termed tissue, and which build up the many-celled organism of genuine animals and plants.

The different classes of very varied forms which constitute the kingdom of the Protista, I have described more fully in various works, and have given them a somewhat different arrangement and limitation; thus especially in my "Studies on the Monera, the Infusoria, and the Radiolaria," also in my "Theory of the Gastræa" (1873). A shorter treatise on "The Protista Kingdom" appeared in the *Kosmos*, and contains "a popular survey of the domain of the lowest living creatures." However, the brief system of the Protista appended to this treatise (like subsequent and similar attempts by other naturalists) can lay claim only to being a preliminary endeavour systematically to solve these difficult questions, and the same applies also to the improved version of this system, which I am about to give here. There will have to be many other attempts made, from different points of view, before we can obtain a satisfactory insight into the systematic arrangement of the classes of Protista, and into the phylogenetic relationship upon which it is based.

However, very much has already been accomplished by the attempts hitherto made; thus, more especially, we have now the important conviction that the large classes of Protista which are so rich in forms (the Diatomea, the Mycetozoa, the Rhizopoda, and the Ciliata, for instance) represent independent series of development of one-celled forms of life, perfectly distinct from genuine many-celled animals and plants. Formerly the Bacteria and Mycetozoa were classed with Fungi, the Siphonea with Mosses, the Thalamaria with Molluscs, the Radiolaria with Echinoderms, the Ciliata with Worms, and naturalists endeavoured to trace the relationships between these wholly different

classes; but now such erroneous classifications are no longer possible.

The surprising discoveries of the last ten years, and, above all, the grand results of the *Challenger* Expedition, have revealed to us—in several independent classes of Protista—an immense variety of remarkable and new forms of life, such as, in fact, we had formerly no idea of. The depths of the ocean, and particularly the immense deep-sea basin of from 6000 to 9000 metres in depth, were, thirty years ago, considered to be lifeless deserts, not inhabited by any living creature. The contrary has proved to be the case since the investigations made by the *Challenger* Expedition, under the direction of Sir Wyville Thompson and Dr. John Murray (1873–1876). These ocean-depths are now known to be inhabited by many thousand varieties of wonderful Protista, which, by the incredible beauty and variety of their one-celled structure of body, surpass everything of the kind hitherto known. This discovery has opened up to us a new world for investigation and study, and has extended our knowledge of the biological domain in a way which would formerly have been considered inconceivable. The grand results of this *Challenger* Expedition have been published by the English Government with unparalleled liberality, and the work already consists of over thirty large folio volumes, with many thousands of plates. Several hundreds of these represent only one-celled new forms of life from the Protista domain.

As an example of what an amazing effect this discovery has had in extending our morphological horizon, I must here mention the Radiolaria, the prettiest of all the classes of Protista and the richest in forms. Plates XV. and XVI.

show a few dozen different forms of them. The first two species of these flinty-shelled marine Rhizopoda were described in 1834 by Meyer. Subsequently, in 1847, Ehrenberg discovered about 300 fossil species of them in the island of Barbadoes in the Antilles; he, however, only knew their neat, trellised, flinty shells; of their organization he knew nothing. An account of their organization was first given by the great Berlin biologist, Johannes Müller, in his last work; he distinguished 50 species which he had himself observed in the Mediterranean, and divided these again into 20 genera. I myself, directly after his death, in Messina, continued the investigations of my ever-lamented master; and in 1862, in a monograph on the Radiolaria, gave an account of 144 new species with illustrations. After this, Richard Hertwig, in 1879, made us acquainted with other new forms of them, and he was also the first to offer convincing proofs that their whole organism, in spite of its wonderful complexity, is formed of a *single cell.* The deep-sea dredgings of the *Challenger* then gave further proofs that the extensive domain of the deep beds of the ocean are covered with "Radiolaria-slime," a fine kind of chalk-like powder, which consists almost entirely of milliards of these neat little flinty shells; many thousands of them go to a grain. In my systematic account of these "*Challenger*-Radiolaria," which I published in 1887 (in three volumes, with 140 plates), I distinguished 4 legions, 20 orders, 85 families, 739 genera, and 4318 species. (Compare my "Allgemaine Naturgeschichte der Radiolarien," Berlin, 1887.)

The system of the Diatomea and of the Thalamaria or Foraminifera, like that of the Radiolaria, has also been

increased to an amazing degree by the magnificent discoveries of the *Challenger* Expedition. And various other valuable contributions have been presented as the result of the unflagging industry of many of the younger scientific men. But no less valuable than this quantitative increase in the extent of our knowledge of the Protista is the qualitative increase in the depth of our knowledge generally, which is due to these discoveries. Our conceptions of the first development of organic life, of the importance of the one-celled organism, of the relations between the Protista and the Histons, etc., have become clearer and been more firmly established. On the one hand, the probability of a polyphyletic origin for the Protista-domain from an independent development of numerous separate tribes of one-celled organisms has become more and more evident; on the other hand, it seems highly probable that numerous species of one single class of Protista are of monophyletic origin, derived from a single common primary form. Thus, for instance, I have shown that all the 4318 species of Radiolaria represent merely modifications of four original types, and that these four primary forms also can be phylogenetically derived, by divergence, from one simple globular cell (*Actissa,* Plate XVI., Fig. 1). Compare Plates XV. and XVI.

The *cell-theory* also has been immensely advanced by these new investigations of the Protista. The discovery of the Monera made the hypothesis of spontaneous generation conceivable, and showed us that the cytod, not the cell, is the first form of life; the nucleated cell arose secondarily out of the non-nucleated cytod. The minute Bacteria, which must likewise be accounted among the Monera, have

shown us that the minutest and most inconspicuous forms of life play the chief and most significant part in the struggle for existence; hundreds of thousands of human lives every year succumb to the attacks of the bacilli of tubercules, of cholera, typhus, various infectious fevers, etc. The Syncytia, or the gigantic many-kernelled cells, show us the astonishing degree of organization which the single cell can attain to; the Siphoneæ-cell becomes a flowering plant, with root, stalk, and leaves (Fig. 17); the Polythalamia-cell becomes a mollusc, with a many-chambered, calcareous nautilus shell. The cell-heaps, or Cœnobia, of the sociable Protista (Volvocineæ, Catallacta, etc.) teach us how the many-celled organism arose originally from the one-celled organism; they form the transition to the histons with their tissues. On account of these important advances in the plastid-theory, we can now clearly distinguish the following five stages in the development of organic life: (1) the cytod; (2) the cell; (3) the syncytium; (4) the cœnobium; (5) the histon.

The phylogenetic classification of the whole organic world will obtain a different system from our above remarks, according as the physiological or the morphological point of view may be regarded as decisive. If the physiological differences in the change of substance be considered as decisive, the old-fashioned division of vegetable and animal kingdoms may be retained. But if, on the other hand, the morphological differences in the structure of the body are regarded as more important, then we must first of all separate the one-celled from the many-celled organisms; the simple Protista and the composite Histons then appear to form the two principal domains of the organic world

(see p. 59). In each of these main divisions we can again distinguish two subdivisions, one with phytoplasm and vegetable change of substance, the other with zooplasm and animal change of substance. Still we must not forget that the large majority of one-celled organisms belong to independent series of development, to phyla of a neutral domain of Protista.

SYSTEM OF THE ORGANIC WORLD UPON THE MORPHOLOGICAL BASIS.

Division of Organisms into Protista and Histons by reason of the structure of their body and their cell-formation.

First Organic Kingdom. *One-celled organisms: Protista.*	Second Organic Kingdom. *Many-celled organisms : Histons.*
Organisms which throughout life mostly remain *one-celled* (Monobia), more rarely by repeated division forming loose *heaps of cells* (*Cœnobia*); but *never genuine tissue.* Propagation mostly asexual (Monogonic).	Organisms which are one-celled only at the beginning of their existence, subsequently many-celled, and always form *tissue* (*Histobia*) by the firm union of the associated cells. Propagation mostly sexual (Amphigonic).
Subdivisions of the Protista.	Subdivisions of the Histons.

A. *Primæval Plants: Protophyta.*	B. *Primæval Animals: Protozoa.*	C. *Tissued Plants: Metaphyta.*	D. *Tissued Animals: Metazoa.*
A. Character:	B. Character:	C. Character:	D. Character:
One-celled organisms with vegetable change of substance (Reduction and Synthesis).	One-celled organisms with animal change of substance (Oxidation and Analysis).	Many-celled organisms with vegetable change of substance (Reduction and Synthesis).	Many-celled organisms with animal change of substance (Oxidation and Analysis).
Main Groups:	Main Groups:	Main Groups:	I. Main Group:
I. *Phytarcha.*	I. *Zoarcha.*	I. *Thallophyta.*	*Cœlenteria.*
Non-nucleated plastids (Cytods).	Cytods (non-nucleated plastids).	With Thallus (Thallus plants).	Tissue animals without body-cavity (always without anus).
II. *Diatomea.*	II. *Cytarcha.*	II. *Mesophyta.*	II. Main Group:
One-celled plants with bivalved flinty shells.	Simplest one-celled animals without cilia movements (Lobosa).	(Prothallota.) With prothallium (middle plants).	*Cœlomaria.* Tissue animals with body-cavity (mostly with anus).
III. *Cosmaria.*	III. *Infusoria.*	III. *Anthophyta.*	A. *Pseudo-cœlia.*
One-celled plants with bifid cellular covering.	One-celled animals without cilia movements.	(Phanerogamæ.) With flowers (flowering plants).	With a split-formed body-cavity (without cœlomic pouches).
IV. *Palmellaria.*	IV. *Rhizopoda.*		B. *Entero-cœlia.*
One-celled plants with fringed spores.	One-celled animals with pseudopodia (root-feet).		With true body-cavity formed out of two cœlomic pouches.
V. *Siphonea.*			
One-celled plants with pseudo-cormus.			

SYSTEM OF THE ORGANIC WORLD UPON THE PHYSIOLOGICAL BASIS.

Division of Organisms into Plants and Animals, by reason of their vital activities, more especially their change of substance.

First Organic Kingdom. *Plants: Plantæ.*	Second Organic Kingdom. *Animals: Animalia.*
Reducing-organisms (with chemico-synthetic function) change the living power of sunlight into the chemical elasticity of organic combinations, more especially albumen (plasson). Secretion of oxygen, absorption of carbonic acid and ammonia.	Oxidizing-organisms (with chemico-analytical function) change the elasticity of organic combinations into the living power of warmth and of motion (muscle and nerve activity). Absorption of oxygen, secretion of carbonic acid and ammonia.

Subdivisions of Plants.		Subdivisions of Animals.	
A. *Primordial Plants: Protophyta.*	C. *Tissue Plants: Metaphyta.*	B. *Primordial Animals: Protozoa.*	D. *Tissue Animals: Metazoa.*
A. Character. (See p. 59, A.)	C. Character. (See p. 59, C.)	D. Character. (See p. 59, B.)	D. Character. (See p. 59, D.)
Main Groups:	Main Groups:	Main Groups:	Main Groups:
I. *Phytarcha.* 1. Probiontes 2. Chromaceæ II. *Diatomea.* 3. Coccochromia 4. Placochromia III. *Cosmaria.* 5. Closterieæ 6. Desmidieæ IV. *Palmellaria.* 7. Protococceæ 8. Xanthelleæ V. *Siphonea.* 9. Botrydieæ 10. Caulerpeæ	I. *Thallophyta.* (Thallus plants.) 1. Algæ 2. Fungi I. *Mesophyta.* Middle plants (Prothallota). 3. Muscinæ 4. Filicinæ III. *Anthophyta.* Flowering plants (Phanerogamæ). 5. Gymnospermæ 6. Angiospermæ 6 A. Monocotylæ 6 B. Dicotylæ	I. *Zoarcha.* 1. Zoomonera 2. Bacteria II. *Cytarcha.* 3. Lobosa 4. Gregarinæ III. *Infusoria.* 5. Flagellata 6. Catallacta 7. Ciliata 8. Acinetæ IV. *Rhizopoda.* 9. Mycetozoa 10. Heliozoa 11. Thalamaria 12. Radiolaria	I. *Cœlenteria.* (Low Animals). 1. Gastræades 2. Spongiæ 3. Cnidaria 4. Platodes II. *Cœlomaria.* (Higher Animals). 5. Helminthes 6. Mollusca 7. Echinoderma 8. Articulata 9. Tunicata 10. Vertebrata

TABULAR SURVEY

Of the first five stages of organic life, with regard to the analogous development of cells in the vegetable and animal kingdoms.

Stage of life.	*Form-character.*	*Vegetable group.*	*Animal group.*
I. First stage of organic life: *Cytoda.* Non-nucleated plastids.	*Monera.* The entire developed body consists of a simple cytod (of a non-nucleated plastid).	*Phytomonera.* Probiontes. (The first beginnings of life, or Probia.) Chromaceæ (Chroococceæ and Nostochineæ).	*Zoomonera.* Lobomonera, Rhizomonera, Bacteria (Sphærobacteria and Rhabdobacteria).
II. Second stage of organic life: *Monocyta.* One-kernelled cells, living singly (Monobia).	*Monocyta.* The entire developed body consists of a single-kernelled cell. (One-celled organisms in the strictest sense.)	*One-celled Plants.* Solitary forms of the Diatomeæ, Cosmariæ (Closterieæ), and Palmellaria.	*One-celled Animals.* Monocystida, Monacinetæ, solitary forms of the Rhizopoda and Infusoria. (Many Flagellata, most Ciliata.)
III. Third stage of organic life: *Syncytia.* Many-kernelled cells, living singly (Plasmodia).	*Syncytia.* The entire body consists of one single gigantic cell, which contains within its voluminous body numerous kernels.	*Vegetable Syncytia.* Siphoneæ (Cœloblastæ), Botrydieæ, Codiaceæ, Caulerpaceæ.	*Animal Syncytia.* Mycetozoa (Myxomycetes), Actinosphærium, Polythalamia with many kernels.
IV. Fourth stage of organic life: *Cœnobia.* Cell-heaps, or simple communities of one-celled organisms.	*Cœnobia.* The entire body consists of a loose community of one-celled creatures, but does not as yet form any firm tissue.	*Vegetable Cœnobia.* Social forms of the Diatomeæ, Cosmariæ (Desmidiaceæ), and Palmellaria.	*Animal Cœnobia.* Polycystidia and social Ciliata (Carchesia), Synacinetæ. Most of the Flagellata, Catallacta, Polycyttaria.
V. Fifth stage of organic life: *Histons.* Organisms forming cell-tissue.	*Histons.* The entire body consists of one or several tissues formed of a band of many cells.	*Metaphyta.* Tissue plants. I. Thallophyta (Thallus plants). II. Cosmophyta (Stem-plants).	*Metazoa.* Tissue animals. I. Cœlenteria (without body-cavity). II. Cœlomaria (with body-cavity).

CHAPTER XVIII.

PEDIGREE AND HISTORY OF THE KINGDOM OF THE PROTISTA.

Questions of Beginnings.—Principles for the Phylogeny of the Kingdom of Protista.—The Earliest Roots of their Pedigree.—Monera.—Phytomonera as the Beginnings of Life.—Probiontes.—Variously repeated Spontaneous Generation of Probia.—Zoomonera (Rapacious Monera).—Bacteria (so-called Cleft-fungi).—Chromaceæ (Chroococceæ and Nostochineæ).—Phytarcha and Zoarcha.—Main Groups of One-celled Organisms. — Diatomea. — Cosmaria. — Palmellaria. — Volvocineæ.—Xanthelleæ.—Cacocyta.—Siphonea.—Amœbina (Lobosa).—Gregarinæ.—Whip-swimmers (Flagellata).—Flimmer-balls (Catallacta).—Infusoria.—The Cell-soul of the Ciliata.—Acinetæ.—Root-footers (Rhizopoda).—Fungus Animalcules (Mycetozoa).—Sun Animalcules (Heliozoa).—Chambered Animalcules (Thalamaria).—Ray-streamers (Radiolaria).—Deep-sea Sediments.

THE old proverb that "every beginning is difficult" applies to science also, and especially to such a young science as phylogeny. The enormous progress it has made during the last twenty years, owing to the industrious investigations of many excellent morphologists, has enlightened us in the most welcome manner on the origin and the development of numerous animal and vegetable groups. Still, but little has been offered that can give us safe ideas as to the origin of the earliest primary groups, of the formation of that simplest primordial creature from which all the others have

to be derived. The beginning of organic life on our earth, the beginning of the earliest primæval creatures or Protista, the beginning of their transformation into higher forms of life, the beginning of the characteristic organization in these higher groups—all these and similar opening questions are, in fact, very difficult to answer, and they are still regarded by many naturalists as insoluble problems.

But I think that, for reasons already stated, and especially from the discussions in our last chapters, that the reader has become sufficiently convinced that we are not justified in hopelessly giving up all thought of ever being able to solve these problems. Difficult and obscure these questions of the beginnings certainly are; yet the marvellous progress which biological investigation has made within the two last decades, the grand discoveries in comparative anatomy and physiology, ontogeny, and palæontology, and above all the fuller knowledge we have obtained of cell-life and the organization of the Protista, have furnished us with many new and powerful means for answering these questions. In several of the large and multiform groups of Protista, for instance, in the Radiolaria and Thalamaria, the Diatomea and Cosmaria, we can already satisfactorily recognize the original relationships of the different groups of forms, and can trace many of them back to common simple original forms. And we can also form a very satisfactory idea as to the importance and origin of these primary forms, the beginning of their historical development. We can, in fact, even now, with full assurance, lay down certain principles as a general guide for the investigation of the pedigree of the Protista.

As *fundamental principles for the phylogeny of the*

kingdom of the Protista, we may even nowadays set up the following as the leading ones: 1. The great majority of Protista, in a developed state, possess an organization which must be conceived as consisting of one single cell. 2. And even though this organization is often comparatively complicated, and seems to exceed the character of a single cell, it can, nevertheless, owing to peculiar transformations, be traced back to a *simple* cell. 3. This simple primordial cell in reality represents merely a minute living lump of plasma, —with two different though closely allied constituent parts, the inner *cell-kernel* (Caryoplasm) and the outer *cell-substance* (Cytoplasm). 4. The general vital activities are divided between these two active primary constituent parts of the cells in such a manner that the inner *cell-kernel* undertakes the function of propagation and *inheritance,* the outer *cell-substance* undertakes the work of nutrition and *adaptation.* 5. All the other constituent parts of the one-celled body of the Protist, more especially the various formations of the skeletons and shells, are *passive plasma products,* and have arisen only secondarily from the interaction of those two active, primary constituent parts. 6. In a physiological respect, the Cytoplasm of the Protista is either *Phytoplasm* (synthetic or reducing plasma with vegetable change of substance) or *Zooplasm* (analytical or oxidizing plasma, with animal change of substance); the former characterizes the primordial plants (Protophyta), the latter the primordial animals (Protozoa). 7. Originally Zooplasm arose out of Phytoplasm by division of labour, inasmuch as it is only Phytoplasm that is capable of originating directly out of anorganic combinations by the influence of sunlight. 8. Those Protista which, in a de-

veloped state, are many-celled (cell-heaps or Cœnobia), have originally arisen out of one-celled primary forms, by the repeated division and the permanent union of the part-products. 9. All one-celled Protista must originally be derived from non-kernelled cytods (Phytarcha and Zoarcha); the simplest of these are the Monera (Phytomonera with phytoplasm, and Zoomonera with zooplasm); cell-kernel and cell-substance are the first differentiation-products of the simple plasson (or of the non-kernelled Moneronplasma). 10. The earliest Monera, which represent the very first primary forms of all other Monera, arose by spontaneous generation (autogeny) out of anorganic combinations (see Chapter XV.). 11. The two kingdoms of the Histons, the many-celled and tissue-forming organisms (animal and vegetable kingdoms), developed originally out of the kingdom of the Protista. 12. The large majority of Protista stands in no direct relationship to these primary forms of Histons, but belong to independent, polyphyletic groups of Protista.

These twelve fundamental principles contain the most important considerations that must form our guide in tracing the pedigree and history of the kingdom of Protista. On the strength of these principles, and of our former observations on general phylogeny and its records, we may now at once turn to the examination of these Protista. And in doing so—guided by physiological considerations—we shall not separate primæval plants and primæval animals (see p. 59), but, on account of morphological comparisons, take the historical development of the kingdom of the Protista as a whole.

The first beginning of the historical development and

pedigree of the Protista, as well as of that of the organic world generally, will have in any case to start with the Monera, those wonderful "*organisms without organs*," which have already been discussed in our eighth and sixteenth chapters. As we there already convinced ourselves, these remarkable Monera are not only the simplest of all known forms of life, but, in fact, the *simplest organisms conceivable;* for their entire and fully developed body is merely a simple, soft atom of plasson, a minute piece of living plasma, in which we are unable, either microscopically or micro-chemically, to discover any internal structure, any combination of different constituent parts. Sometimes this minute living lump of plasson is round, sometimes of an indefinite and changing shape. It is irritable, sensitive, and capable of moving like any other organism; it takes nourishment and propagates itself (by division), and yet it lacks special organs for these vital activities.

And while again laying stress upon the fact of the *perfect simplicity of the moneron-body*, I must at the same time remind the reader that this by no means excludes the possibility of there being a very complicated molecular structure, a complex combination of organized groups of molecules (plastidules or mi-cells). On the contrary, we may, for general reasons, and with full assurance, assume some such arrangement *theoretically*, although it is not *empirically* demonstrable and not perceptible through the microscope. One portion of the Monera, for example, the Protomyxa, given on Plate I. vol. i., as well as some forms of Biomyxa and Protamœba (vol. ii. p. 72), are of considerable size; and yet, even with the assistance of the most powerful

magnifying glass, we are unable to perceive any definite structural arrangement in the homogeneous, transparent plasma of which their bodies consist. We may, therefore, assume that they are composed of nothing but homogeneous molecules of plasson (plastidules or mi-cells), and that these molecules are separated by coverings of water. Like all molecules, these likewise are much too minute to be recognized even with the aid of our most powerful microscopes.

As regards the *metabolism of the Monera,* and at the same time as regards their importance as "the beginnings of life," we must distinguish two different classes of these simplest primæval creatures—*Phytomonera* and *Zoomonera.* The Phytomonera are formed of phytoplasm, have also the capacity of synthetically producing plasson from anorganic combinations, and of changing the living power of sunlight into the chemical elasticity of organic combinations. The Zoomonera, on the other hand, consist of zooplasm, and do not possess the above-mentioned power of assimilating; they nourish themselves by the acquisition of plasma from other organisms, and change the elasticities obtained from these into the living power of warmth and of mechanical motion. To these Zoomonera (with animal change of substance) probably belong most of the monera-forms as yet described (vol. i. p. 189); to the Phytomonera, on the other hand, belong the most ancient of all organisms, the Probiontes.

Probiontes (or *Protobia*) we call those simplest forms of life which, on the one hand, on account of the absolute simplicity of their plasson-body, and, on the other, on account of their vegetable metabolism, must be regarded as

the most ancient primæval sources of all life. The best description of them has been given by Naegeli in his large work already mentioned, "Mechanico-Physiological Theory of the Doctrine of Descent" * (compare above, vol. i. p. 232). He defines them as very minute living atoms of plasma, which by the process of spontaneous generation (in the sense described in vol. i. p. 401) arose directly, by "mi-cellular-organization," from the albuminous combinations that originated spontaneously. He distinguishes two stages "in the introductory period which exists between anorganic nature and the lowest organisms known to us. The first stage is represented by the synthesis of the albuminous combinations, and in their organization into mi-cells (or plastidules); the second stage by the progressive development of the primordial mass of plasma up to the simplest organisms known to us." Naegeli thinks that these Probia or Probiontes are much too small to be seen even with the aid of our most powerful microscopes. And yet there is no reason for supposing that these Probiontes should not be able gradually to attain a much greater size by simple growth (like growing crystals). I assume that the larger forms are distinctly visible when greatly magnified, and that without any sharp boundary they turn into the comparatively large Zoomonera. Perhaps many of the smallest particles of plasma, such as we meet with freely everywhere in fresh and salt water, are independent Probiontes. We are in the habit of considering them to be detached particles of plasma from destroyed or decaying corpses of animals and plants. However, as a rule, there is no strict proof of this. And who can prove to us that

* "Mechanisch-physiologische Theorie der Abstammungs-lehre."

these Probia have not shortly before arisen by spontaneous generation?

The discussions on spontaneous generation which Naegeli (*l.c.*, pp. 82–101) appends to his account of the Probia are among the best and most astute observations we have on this very important question. I entirely agree with him, where he begins this interesting chapter with the following remarks: "The origin of organic from inorganic matter is, first of all, not a question of experience and of experiment, but a *fact* that follows from the law of the preservation of force and matter. If in the material world everything stands in causal connection, if all phenomena take place in a natural manner, then organisms likewise—which are constructed of the same substances, and finally dissolve into the same substances of which inorganic nature consists—must in their first beginnings have originated out of inorganic combinations. To deny spontaneous generation is to proclaim miracles." This significant and unquestionably correct conception of the first origin of life ought to be carefully considered by the many naturalists who, owing to dogmatic prejudices, are still opponents of the theory of spontaneous generation in any form.

Twenty-three years ago, when I set up spontaneous generation, in the form here given (Autogeny), as an indispensable hypothesis of the general doctrine of development, it was universally rejected. In those days Virchow's famous proposition, "Omnis cellula e cellula" (every cell has proceeded from a cell), reigned supreme. It was considered a parallel to Harvey's famous old proposition, "Omne vivum ex ovo" (all living things have proceeded from an egg). Both propositions hold good in the case of

the large *majority* of organisms. Both propositions, however, become false dogmas if they are regarded as *universally* applicable.

For they do not apply, and cannot apply, in the case of the lowest forms of life. If we rationally take into account all the circumstances that come into consideration here, we shall find ourselves convinced that the most ancient cells did not arise out of cells, but from non-nucleated cytods, from *Monera;* and these Monera, and more especially the earliest Probiontes, can originally have arisen only by spontaneous generation in the sense spoken of above.

As I have already stated, and as Naegeli also assumes, it is very probable that such acts of spontaneous generation have been frequently repeated, especially at such times when the conditions required for it existed in inorganic nature. Perhaps they take place daily still, without our being able to observe them owing to our instruments not being sufficiently powerful. The necessary conditions for this in inorganic nature are still wholly unknown to us; and the spontaneous origin of minute Probiontes, corpuscles of plasson, which, even when strongly magnified, are scarcely visible, could scarcely be proved even under the most favourable circumstances. As regards the still living Monera, however, we find ourselves with the following alternative: *either* they are descended directly from the most ancient Monera that first came into existence (or were "created"), and if so they have propagated themselves for many millions of years unchanged and retained the original form of simple particles of plasma; *or* the Monera of to-day came into existence at a much later date in the course of the organic history of the earth by repeated acts

of spontaneous generation, and in this case spontaneous generation may take place nowadays just as well, and can be repeated ever so often. It is obvious that the latter supposition is much more probable than the former.

If the hypothesis of spontaneous generation is not accepted, then we should have at this one point in the theory of development to take refuge in the miracle of a supernatural creation. We should have to assume that the first organisms, or the first few organisms from which all the others are derived (at all events, the simplest Monera or primæval cytods), were created as such, and that the Creator conferred upon them the capacity of developing further in a mechanical way. I leave the reader to choose between this miraculous idea and the hypothesis of spontaneous generation. In my opinion the idea that the Creator should have interfered at this one point in the regular course of the development of matter, which otherwise proceeds entirely without His co-operation, must be as unsatisfactory to a credulous as to a scientific mind. If, on the other hand, we assume for the origin of the first organisms the hypothesis of spontaneous generation, which, for reasons discussed above and especially by the discovery of the Monera, has lost its former difficulty, we obtain an uninterrupted, natural connection between the development of the earth and the organisms which it has produced; and, further, we also recognize in the last still doubtful point *the unity of all nature, and the unity of her laws of development.*

The *Probiontes,* or primordial *Phytomonera,* by an alteration in their metabolism, produced the *Zoomonera,* those monera which are not capable of assimilating or of synthetically forming plasma themselves, but have to acquire

for their nutrition plasma that has already been formed by other organisms. To these belong probably most of the Monera which we have formerly described (Protamœba, Protogenes, Protomyxa, etc.). These "rapacious animal-monera" found it more convenient to procure their nourishment directly from their vegetable sisters than to form the plasma synthetically themselves. Such an alteration in the change of substance necessarily produced the most important

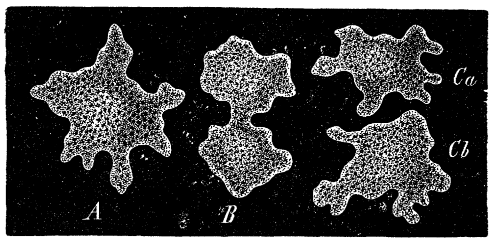


FIG. 8.—Protamœba primitiva, a fresh-water Moneron, much enlarged. *A.* The entire Moneron with its form-changing processes. *B.* It begins to divide itself into two halves. *C.* The division of the two halves is completed, and each now represents an independent individual.

consequences; physiologically speaking, this would give us the derivation of the animal from the vegetable kingdom. There is absolutely nothing mysterious about it; for even many of the higher plants have accomplished the same essential alteration and changed their synthetical phytoplasm into analytical zooplasm; for instance, all those parasites which take their plasma directly from other plants, the well-known parasitical plants, destitute of green leaves, from the groups of orchids, Orobancheæ, Cuscuteæ, Cytineæ, etc. They are all proved to be derived from higher plants with green leaves, which possessed an entirely opposite metabolism (compare above, vol. i. p. 241). This same very

important and essential differentiation, which was often accomplished in these different groups, occurred for the first time when zoomonera developed out of phytomonera.

As a special group of the Zoomonera we must class the *Bacteria,* those extremely remarkable small organisms which at present play an extraordinarily prominent part in medical science as the producers of numerous diseases—putrescence, fermentation, etc. Sometimes they are globular (Sphærobacteria, *e.g.* Micrococcus), sometimes like little rods (Rhabdobacteria, *e.g.* Bacillus). Most Bacteria are so minute in size that they are invisible except under the most powerful magnifying glass, and many even then only when they have been coloured. A single drop of water from some putrid fluid can contain milliards of them. Many show peculiar quivering movements, and have therefore been called *Vibriones.* The entire minute body of the Bacteria consists of a homogeneous little lump of plasma, like all other Monera. As there is no cell-kernel, they cannot be termed cells; but are rather simple cytods. They increase simply by division. Many of the most dangerous illnesses (cholera, tubercular diseases, splenitis, leprosy, etc.) are produced by peculiar species of Bacteria; in the shortest space of time, these minute Protista, by developing in masses and also by the production of a peculiar poison, can destroy the tissues of the human body and cause death. In many of our college manuals the Bacteria are still classed as one-celled plants, although they neither form a cell nor show a vegetable change of substance. They are generally called fissiparous Fungi (Schizomycetes), although they do not possess a single characteristic of genuine Fungi.

Many botanists class the group of the *Chromaceæ* (or *Cyanophyceæ*) with the Bacteria, and form the unnatural class of so-called fissiparous algæ (Schizophyta). What the two groups have in common is their increase by simple division and the *want of the cell-nucleus;* hence the Chromaceæ also are not genuine cells, but mere cytods. Their change of substance is vegetable (plasma-forming), not animal (plasma-consuming), as in the Bacteria. And whereas the zooplasm of the latter is colourless, the phytoplasm of the former appears a blue-green owing to a peculiar colouring matter (phycocyan). As a special membrane encloses the non-nucleated plastids, we must call them *Lepocytoda.* Many Chromaceæ show peculiar movements. In the case of the *Chroococceæ* the two cytods which were propagated by division soon separate from each other, whereas in the *Nostochineæ* they form a string by placing themselves side by side. In both groups of the Chromaceæ the cytods frequently secrete a gelatinous mass, in which they remain in social unity (Cœnobia). They are met with everywhere in quantities, in water and in damp earth.

The Protista discussed above, both the *Phytarcha* (with vegetable change of substance and phytoplasm) as well as the *Zoarcha* (with animal change of substance and zooplasm), all agree in one most important characteristic: they do not as yet possess a cell-kernel or nucleus, and can, therefore, not be termed "cells." The separation of the *plasson* into the cell-kernel (caryoplasm) and the cell-substance (protoplasm) takes place only at the second stage of the Protista kingdom, that of the actual *one-celled individuals.* Among these we can, in general, distinguish three groups; the

circumstances of their mutual relationships, however, are very complicated. A first group is formed by the so-called "one-celled plants," with phytoplasm and vegetable change of substance (plasma-forming or "plasmogenous"), the Diatomeæ, Cosmariæ, Palmellaria, and Siphonea. To the second group belong the actual "one-celled animals," with zooplasm and animal change of substance (plasma-consuming or "plasmophagous"), most Infusoria (especially Ciliata and Acinetæ) and Rhizopoda (especially Thalamaria and Radiolaria). And yet in many other Protista the distinctive peculiarity of the change of substance is not pronounced, or it is connected in so extraordinary a manner with contrary morphological characteristics, that an endless dispute arises as to whether they are to be regarded as "primæval plants" or "primæval animals." To this third group, to the "neutral monera," belong, for instance, the Flagellata, the Lobosa, the Gregarinæ, Diatomeæ, and the Mycetozoa.

The *Diatomeæ* (Plate XIV., Fig. 2, 3) form a perfectly independent class of the Protista kingdom, extremely varied in forms, and are characterized by a peculiar bivalved flinty shell. They inhabit the sea and fresh waters in immense masses, and offer an endless variety of the prettiest forms. Most Diatomeæ are small microscopic cells, which either live singly (Fig. 13) or united in great numbers. Many adhere to other objects; but most of them glide, swim, or creep about in a peculiar manner. Their soft cell-substance is of a characteristic brownish-yellow colour, and is always enclosed by a solid and hard flinty shell; this shell is distinguished by a very regular and, in most cases, symmetrical form, very finely cut, and of the neatest and

most varied shapes. The flinty case consists in reality of two halves, but loosely connected, somewhat like a box and its lid. In the seam between them, and perhaps also in a special longitudinal line, are one or two slits, by means of

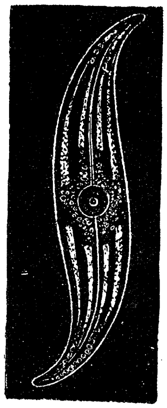


FIG. 9.—Navicula hippocampus, greatly magnified. In the middle of the flinty-encased cell is the cell-kernel or nucleus, together with its kernel-speck (Nucleolus).

which the enclosed soft cell-substance communicates with the outer world. The flinty cases are found petrified in masses, and many rocks, for example, the Tripoli slate polish, the Swedish mountain meal, etc., are in a great measure composed of them. The Diatomea propagate simply by division; in so doing the two valves of the box-shaped flinty-cell are pushed apart, and after the protoplasm has broken by the division of the kernel into two equal halves, each half produces a new valve, which adapts itself to the older half as a box to its lid.

The *Cosmaria*, which resemble the Diatomea, are, however, more closely allied to the vegetable kingdom (see Plate XIV., Fig. 4, 8); they are likewise one-celled Protista, and are also distinguished by the neat and regular shape of their bilateral symmetrical case or covering. This case, however, does not consist of a bivalved flinty shell, but of a bilateral cellular membrane, generally forming two lobes through being slit up towards the centre. This covering often presents a very neat star shape, or forms star-shaped lobes; at other times the Cosmaria cell is regularly triangular, cross-shaped, crescent-shaped, etc. Their propagation is

effected simply by a division of the middle surface; each half then completes itself again by the formation of a new half. Generally (as in the case of the Gregarinæ) the division is preceded by the copulation or commingling of two equal

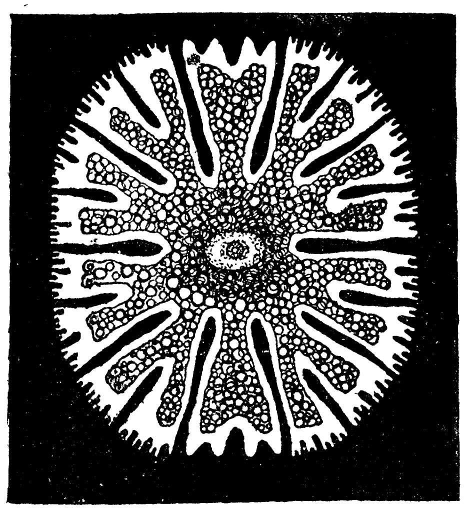


FIG. 10.—Euastrum rota, a one-celled Cosmaria, much enlarged. The entire, neat star-shaped body has the formal value of a single cell. In the centre lies the kernel, and within it the kernel corpuscle or speck.

cells. The large majority of Cosmaria live isolated, and are found everywhere in fresh water (Closterieæ); some, however, live together and form Cœnobia in the form of chains (Desmidieæ); this row of cells leads over to the group of the Zygnemeæ or Conjugatæ, many-celled algæ with filiform thallus.

Closely allied to the Cosmaria we have the *Palmellaria* (Palmellaceæ), a large group of "one-celled algæ," which likewise belong to the primary group of "many-celled

algæ." Just as the Cosmaria (Desmidieæ) have to be regarded as the primary group of the Zygnemeæ, the Palmellaria have to be regarded as the original and primary group of the Conferveæ (or the many-celled green "water-threads"). The Palmellaria cells also are sometimes found living singly as hermits (Eremobia), sometimes sociably united into gelatinous cell-heaps (Cœnobia). To these belong the Protococceæ and the Pleurococceæ; many botanists also include the Pandorinæ and the Volvocineæ, which, however, by most zoologists are regarded as Flagellata, and classed among the Infusoria. In a freely moving state these neutral Protista swim about by means of one or more long oscillating whips, and then resemble genuine Infusoria ("the plant in the act of becoming an animal"), Plate XIV., Fig. 9, 10. In a state of rest, on the other hand, they appear as globular or roundish vegetable-cells of the simplest kind. They propagate, sometimes by simple division (Fig. 11–13), sometimes by the copulation of two homogeneous cells; by becoming unequal they introduce sexual propagation.

Among the Palmellaria belong, probably, also the *Xanthelleæ*, or the so-called "yellow cells," which live in the bodies of many of the lower animals, not exactly as parasites which take their nourishment from them, but as Symbiontes, which are closely united to them for their common good. The animals thus inhabited (worms, radiata, zoophytes of all classes, radiolaria, Fig. 17, p. 94) offer the enclosed Xanthelleæ (Zooxanthella) shelter and protection; they receive from the latter, in return, plasma and starch-flour, which they produce under the influence of sunlight. The "yellow cells" are generally of a simple globular shape,

PLATE XIV.

FUNDAMENTAL FORMS OF PROTOPHYTA.

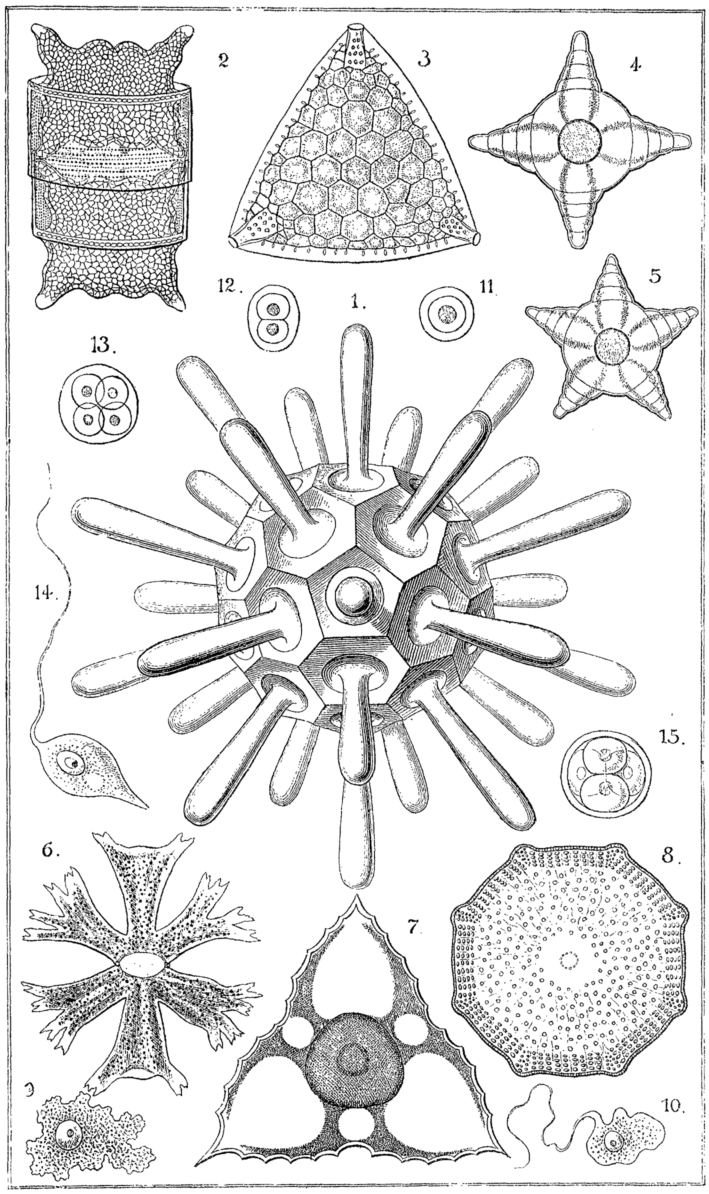
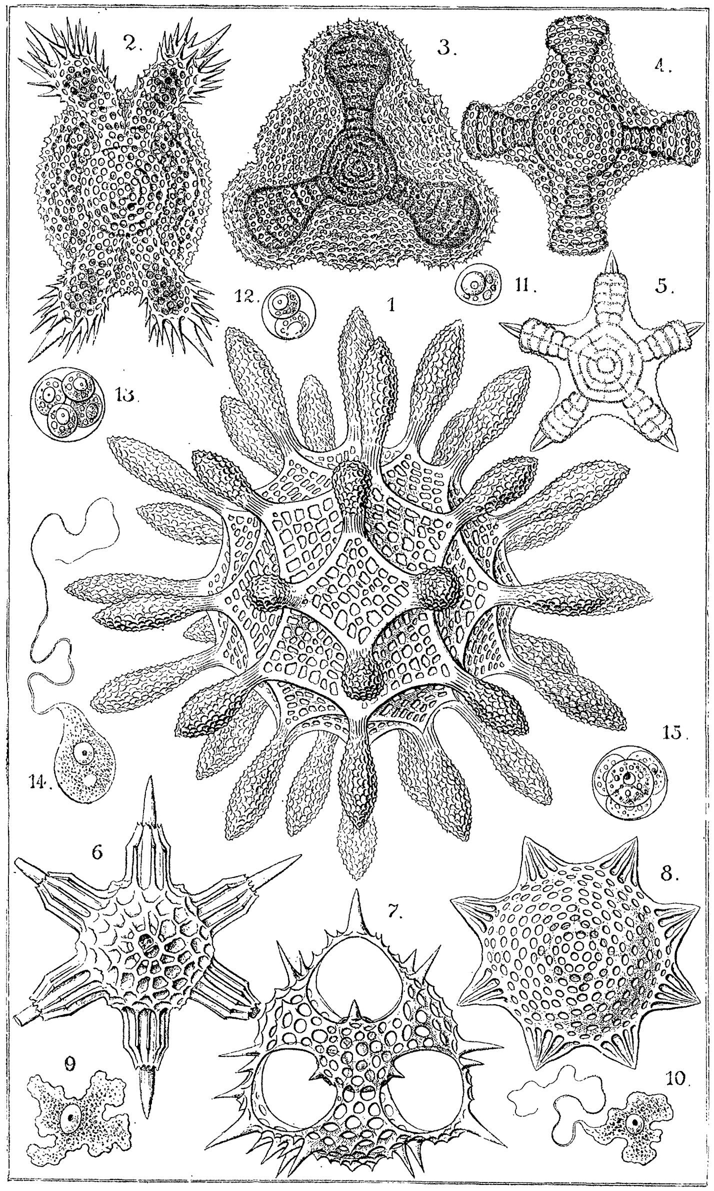


PLATE XV.

Fundamental Forms of Protozoa.



and propagate by division (Plate XV., Fig. 11–13). If the Xanthelleæ are removed from the bodies they inhabit, they secrete a gelatinous substance and change into the Palmella state. If, however, they are placed in plenty of water, they change into Flagellata, into one-celled "swarming-spores with two whips."

The *Labyrinthuleæ*, which live on piles in sea-water, are perhaps allied to the Xanthelleæ. They are spindle-shaped

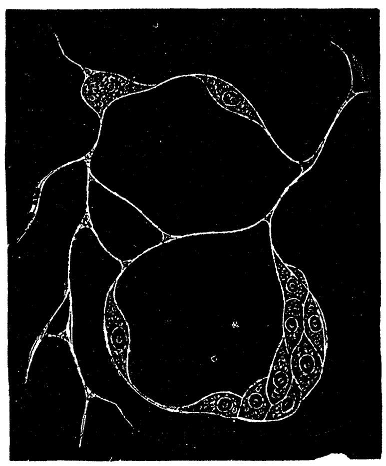


FIG. 11.—Labyrinthula macrocystis, much enlarged. Below is a group of accumulated cells, one of which, to the left, is separating itself from the rest; above are two single cells, gliding along the threads of the retiform labyrinth which form their "tramways."

cells, mostly of a yellow-ochre colour, sometimes united into a dense mass, sometimes moving about in a very peculiar manner. They form, in a manner not yet explained, a retiform frame of entangled threads, and they glide about on the rigid filamentous "tramway" of this frame. From the shape of the cells of the Labyrinthuleæ they might be considered as the most simple plants, and from their peculiar movements as the simplest animals.

A remarkable, but as yet little known group of Protista, are the *Calcocyteæ*, or the "one-celled calcareous algæ." The cell, probably formed of phytoplasm, absorbs in this

case so much carbonate of lime, that it resembles an inorganic corpuscle or a concretion of lime. Sometimes they form simple round discs (Discoliths), sometimes little double discs, like a small shirt-button (Cyatholiths). The small globules which are composed of numerous connected little discs of this kind, the Coccosphæræ, are perhaps Cœnobia of the former; and in like manner the neat Rhabdosphæræ, calcareous globules with radial spicules which project from the polygonal plates of the surface (Plate XIV., Fig. 1). These small Calcocyteæ are found in masses on the surface and at the bottom of the tropical seas, and also fossil in chalk. (Compare Wyville Thompson's "The Atlantic," 1877, vol. i. p. 222.)

A very curious class of "primæval plants" is formed by the *Siphonea;* they are of considerable size, and strangely mimic the forms of higher plants. Some of these Siphonea attain a size of several feet, and resemble a pretty moss (Bryopsis) or club-moss, and in some cases even a perfect flowering plant with stalks, roots, and leaves (Caulerpa, Fig. 17). And yet the whole of this large and outwardly differentiated body consists inwardly of a perfectly simple sack, with the formal value of only a single cell. Numerous little cell-kernels are distributed in the phytoplasm, which lines the inner wall of this gigantic cell-sack. Some propagate themselves only in a non-sexual manner (Caulerpa, etc.); others in a sexual manner (Vaucheria, etc.). These curious Siphoneaæ, Vaucheriæ, and Caulerpæ show us to how great a degree of elaboration a single cytod—although a most simple individual of the first order—can develop by continuous adaptation to the relations of the outer world. Most of them are inhabitants of warm oceans; still some

species are also met with in fresh waters (Vaucheria), or even in damp earth (Botrydium).

While the Protista which we have hitherto been discussing are considered by most naturalists to be "primæval

FIG. 12.—Caulerpa denticulata, a Siphonean of the *natural size.* The entire branching plant, which appears to consist of a creeping stalk with fibrous roots and indented leaves, is in reality only *a single cell.*

plants," those one-celled organisms to which we have now to turn our attention are generally described as "*primæval animals,*" and are divided into the great classes of Infusoria and Rhizopods. The simplest and least differentiated forms of this main group we find to be, in the first place, the

Amœbina or Lobosa. To these belong the naked Amœbæ (Gymnolobosa) and the encased Arcella (Thecolobosa). The common Amœbæ are the type of the simple nucleated, but still structureless *cell*. Perfectly similar, naked, nucleated cells are met with everywhere at the beginning of the development both of genuine plants and of genuine animals. The propagating cells, for instance, of many algæ (spores and eggs) exist for a longer or shorter time in water in the form of naked, nucleated cells, which cannot, in fact, be distinguished from the simple Amœbæ or from the naked eggs of many animals (for instance, of Sponges, Siphonophora, and Medusæ; compare the drawing of the naked egg of the common bladder-wrack in Chapter XIX.). Many naked, simple cells, whether they proceed from an animal or vegetable body, cannot actually be distinguished from an independent Amœba. For the latter is itself nothing but a simple primæval cell, a naked little lump of protoplasm containing a kernel. The contractility of this protoplasm, which the free Amœba shows in stretching out and drawing in its changing processes, is a general vital property of organic plasson, both of animal as well as vegetable plastids. When a freely moving Amœba, which perpetually changes its form, passes into a state of rest, it draws itself together into the form of a globule, and surrounds itself with a secreted membrane. It can then as little be distinguished from an animal egg as from a simple globular vegetable cell (Fig. 13 *A*).

Naked cells, with kernels, like those represented in Fig. 13 *B*, which are continuously changing, stretching out and drawing in formless, finger-like processes, and which are on this account called amœboid, are found frequently

and widely dispersed in fresh water and in the sea; nay, are even found creeping on land. They take their food in the same way as was previously described in the case of the Protamœba (vol. i. p. 191). Their propagation by division

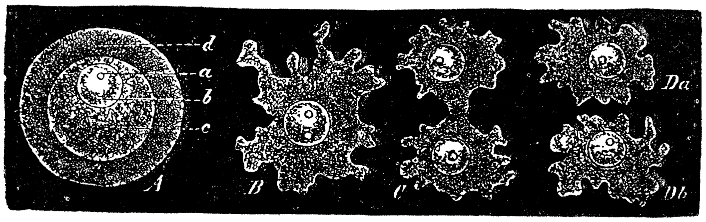


FIG. 13.—Amœba sphærococcus, greatly magnified. A fresh-water Amœba without a contractile vacuole. *A*. The enclosed Amœba in the state of rest, forming a globular lump of plasma (*c*) and enclosing a kernel and a kernel-speck (*a*). The simple cell is surrounded by a cyst, or cell-membrane (*d*). *B*. The free Amœba, which has burst and left the cyst, or cell-membrane. *C*. It begins to divide by its kernel parting into two kernels, and the cell-substance between the two contracting. *D*. The division is completed, and the cell-substance has entirely separated into two bodies (*Da* and *Db*).

can sometimes be observed (Fig. 13 *C*, *D*). I have described the processes in an earlier chapter (vol. i. p. 191). Many of these formless Amœbæ have lately been recognized as the early stages of development of other Protista (especially the Myxomycetæ), or as the freed cells of lower animals and plants. The colourless blood-cells of animals, for example, those of human blood, cannot be distinguished from Amœbæ. They, like the latter, can receive solid corpuscles into their interior, as I was the first to show, in 1859, by feeding them with finely divided colouring matters. Many voracious "migratory cells" of this kind (or Phagocytæ) play an important part in the change of substance of higher animals, and also in many diseases in mankind. However, other Amœbæ (like the one given in Fig. 10) seem to be inde-

pendent "good species," since they propagate themselves unchanged throughout many generations. Besides the real, or *naked*, Amœbæ (Gymnolobosa), we also find widely diffused in fresh water *case-bearing* Amœbæ (Thecolobosa), whose naked protoplasm body is *partially* protected by a more or less solid shell (Arcella), sometimes even by a case (Difflugia) composed of small stones. This shell is often of a very pretty form; in Quadrula, for instance, it is composed of little quadrate plates.

Next to the Lobosa we have the *Gregarines* (*Gregarinæ* or *Sporozoa*). These are one-celled, fairly large parasitical Protista that live in the intestinal tube and in the body-cavity of many animals; they move about and draw themselves together like worms, and were formerly wrongly classed among the Worms. The Gregarinæ differ from the Amœbæ by the want of changing processes, and by possessing a thick but simple membrane enclosing their cell-substance. They can be regarded as Amœbæ which have adapted themselves to a parasitical life, and consequently have encased themselves in a secreted membrane. Sometimes the Gregarinæ remain simple cells, and sometimes form chains of two or three cells. When propagating themselves they contract into a globular form, the kernel dissolves in the protoplasm, and the latter separates into numerous little globules or spores. These surround themselves in spindle-shaped cases, and thus become so-called Psoro-spermiæ (or pseudo-navicellæ). Subsequently a little *Moneron* creeps out of the case, and by newly forming a kernel changes into an *Amœba*. And by the latter growing and enclosing itself in a case it again becomes a Gregarine.

A very remarkable class of Protista is formed by the

Whip-swimmers (*Flagellata,* Fig. 14). Like the Lobosa, they are interesting owing to their not being differentiated, and also by their neutral character, so that most zoologists regard them as one-celled animals, whereas botanists hold them to be one-celled plants. And, in fact, they show as close and important relations to the vegetable as to the animal kingdom. Some Flagellata at an early stage, when freely moving about, cannot be distinguished from the swarming spores of many algæ, whereas others appear allied to genuine animals. Some are green and produce plasma (like Protophyta); others, of the same form, are colourless

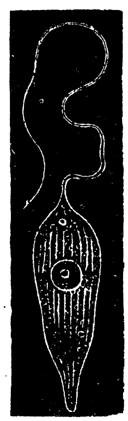


FIG. 14.—A single Whip-swimmer (Euglena striata), greatly magnified. Above is a thread-like waving whip; in the centre is the round cell-kernel with its kernel-speck.

and consume plasma (like Protozoa). Hence the Flagellata are, in reality, neutral Protista, and stand, on the one hand, as near genuine "primæval plants" (Palmellaria) as, on the other, they do to genuine "primæval animals" (Infusoria). Many live singly (Euglena, Fig. 14), others united in Cœnobia or colonies (Volvocineæ). They are found everywhere in masses, both in fresh as well as in salt water. The characteristic part of their body is a very movable simple or compound whip-like appendage (whip or flagellum), by means of which they swim about actively. The red or green Euglenæ and Astasiæ often cause the water suddenly to become red or green in springtime, owing to the immense quantities of them. Some Whip-swimmers (for example, the Euglenæ, Fig. 14) possess a naked cell-body, whereas in

the Thecoflagellata it is surrounded by a membrane. The flint-shelled Peridinia (Dinoflagellata) possesses, in addition, a peculiar belt-whip. The largest and most curious forms are, however, the Sea-lights or Noctilucæ (Cystoflagellata), which emit light in darkness, and often exist in such enormous quantities that the surface of the sea is illuminated for miles. One of these phosphorescent Flagellata (Leptodiscus medusoides) mimics the forms and movements of a genuine medusa, and is nevertheless only a simple umbrella-shaped *cell.*

A very remarkable new form of Protista, which I have named *Flimmer-ball* (Magosphæra), I discovered in September, 1869, on the Norwegian coast (Fig. 15), and

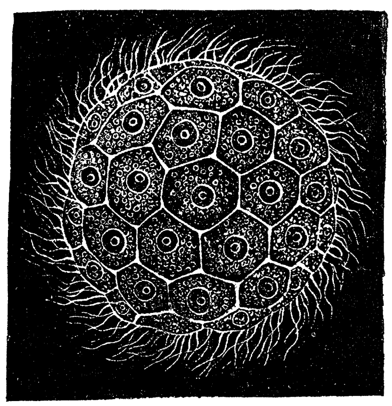


Fig. 15.—The Norwegian Flimmer-ball (Magosphæra planula) swimming by means of its vibratile fringes, as seen from the surface.

have more accurately described in my "Biological Studies" [15] (p. 137, Plate V.). Off the island of Gis-oe, near Bergen, I found swimming about, on the surface of the sea, extremely neat little balls composed of a number (between thirty and forty) of fringed pear-shaped cells, the pointed ends of which were united in the centre like radii. After a time the ball dissolved. The individual cells swarmed about independently in the water like fringed Infusoria, or Ciliata. These afterwards

sank to the bottom, drew their fringes into their bodies, and gradually changed into the form of creeping Amœbæ (like Fig. 13 *B*). These last afterwards encased themselves (as in Fig. 13 *A*), and then divided by repeated halvings into a large number of cells (exactly as in the case of the cleavage of the egg, Fig. 6, vol. i. p. 343). The cells became covered with vibratile hairs, broke through the case enclosing them, and now again swam about in the shape of a fringed ball (Fig. 15). This wonderful organism, which sometimes appears like a simple Amœba, sometimes as a single fringed cell, sometimes as a many-celled fringed ball, can hardly be classed among any of the other Protista, and must be regarded as the representative of a new independent group. As this group stands midway between several of the Protista, and links them together, it may be termed the *Mediator* or *Catallacta.*

A very marked animal character is presented by the vital phenomena of the great class of genuine *Infusoria* (Infusoria), and particularly in that group which are now usually known by the name of ciliated Infusoria (Ciliata). These variously formed and interesting little creatures, which inhabit all the fresh and salt waters of the earth in great numbers, are an example of how far a single animal cell can develop, in its endeavour to perfect itself. For although these ciliated Infusoria show such a power of active and voluntary movements and such fine sensitive feelings that they were formerly generally considered highly organized animacules, they are only *simple cells.* The surface of these variously shaped cells is covered with fine hairs or cilia, which are used for moving about, for feeling, and for taking food. Within lies a simple cell-kernel.

Some propagate themselves by division, others by the formation of buds or spores. The division is often preceded by copulation, or a kind of sexual propagation. In no group of Protista do we so distinctly and undeniably observe the expressions of the *soul-life of the single cell* as in the case of these ciliated Infusoria, and thus they are specially interesting to the monistic theory of the cell-soul. (Compare my treatise on "Cell-Souls and Soul-Cells.")

The *Acinetæ* (Acinetæ), or adherent, sucking Infusoria, are the next relatives of the Ciliata, and are generally mentioned as a special class in the system of Protista. In contrast to the nimble and very active ciliated Infusoria, these one-celled Acinetæ generally adhere rigidly to objects in the water, and put out stiff little sucking-tubes as fine as hairs, and with these they suck up other Infusoria. Like the Ciliata, the Acinetæ propagate sometimes by division, sometimes by budding, or by the formation of moving spores.

But while the Infusoria are mainly of interest, physiologically, as the Protista with the most fully developed cell-soul, we find the largest variety of forms and the greatest morphological divergence in the last group of the Protista kingdom, the *Ray-streamers* (*Rhizopoda* or *Sarcodina*). These remarkable "primæval animals" have inhabited the sea from the most ancient times of the organic history of the earth in an immense variety of forms, sometimes creeping at the bottom of the sea, sometimes swimming on the surface. Only very few live in fresh water or in damp earth. Most of them possess solid calcareous or flinty shells of an extremely beautiful construction, which can be perfectly preserved in a fossil state. They have frequently

accumulated in such huge numbers as to form mountain masses, although the single individuals are very small, and often scarcely visible, or completely invisible, to the naked eye. A very few attain the diameter of a few lines, or even as much as a couple of inches. The name which the class bears is given because thousands of exceedingly fine threads of protoplasm radiate from the entire surface of their naked slimy body; these rays are quasi-feet, or pseudopodia, which branch off like roots (whence the term Rhizopoda, signifying root-footed), unite like nets, and are observed continually to change form, as in the case of the simpler plasmic feet of the Amœboidea, or Lobosa. These ever-changing little pseudo-feet serve both for locomotion and for taking food.

We distinguish among the Rhizopods four classes: the Mycetozoa, Heliozoa, Thalamaria, and Radiolaria.

The first class of Rhizopods is formed by the remarkable *Fungus-animals* (*Mycetozoa*). Formerly they were

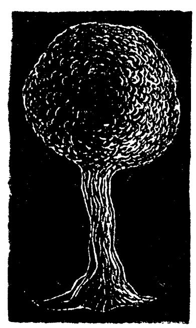


FIG. 16.—A stalked fruit-body (spore-bladder, filled with spores) of one of the Myxomycetes (Physarum albipes), not much enlarged.

generally regarded as moulds, and classed as Slime-moulds (Myxomycetes) in the vegetable kingdom. The botanist De Bary was the first to discover their curious ontogeny, and very justly inferred from this that they were quite distinct from Fungi, and were rather to be considered as lower animals. The mature body is a roundish bladder, often several inches in size, filled with fine spore-dust and soft flakes (Fig. 16),

as in the case of the well-known puff-balls (Gastromycetes). However, the characteristic cellular threads, or hyphæ, of a real fungus do not arise from the germinal corpuscles or spores of the Myxomycetes, but merely naked cells, which at first swim about in the form of Flagellata (Fig. 14), afterwards creep about like the Amœbæ (Fig. 13 *B*), and finally combine with others of the same kind to form large masses of slime, or "plasmodia." This consists of irregular nets of protoplasm, which by constant changing slowly alters its irregular shape. Subsequently they contract into a round lump, and change directly into the bladder-shaped fruit-body. One of these large plasmodia, the Æthalium septicum, is frequently met with in summer, and is known by the name of "tan-flowers;" it forms a beautiful yellow mass of soft mucus, often several feet in breadth, and penetrates tan-heaps and tan-beds. At an early stage these slimy, freely creeping Fungus-animals, which live for the most part in damp forests, upon decaying vegetable substances, on the bark of trees, etc., distinctly show that they belong to the Rhizopods and not to the Fungi.

The second class of the Rhizopods, the *Heliozoa*, includes, among others, the so-called *Sun-animalcules*, which are very frequently found in our fresh waters. As early as last century one was observed by a clergyman in Dantzig, Eichhorn by name, and it has been called after him, Actinosphærium Eichhornii. To the naked eye it appears a gelatinous grey globule of the size of a pin's head. Looking at it through the microscope, we see thousands of fine mucous threads radiating from the central plasma-body, and perceive that an inner layer of cellular substance can be

distinguished from the outer layer, which forms a bladder-like covering. The former contains numerous kernels. The smaller Actinophryssol contains only a single kernel in its cell-substance. Many sun-animalcules envelop their body in a neat little round lattice-case (Clathrulina).

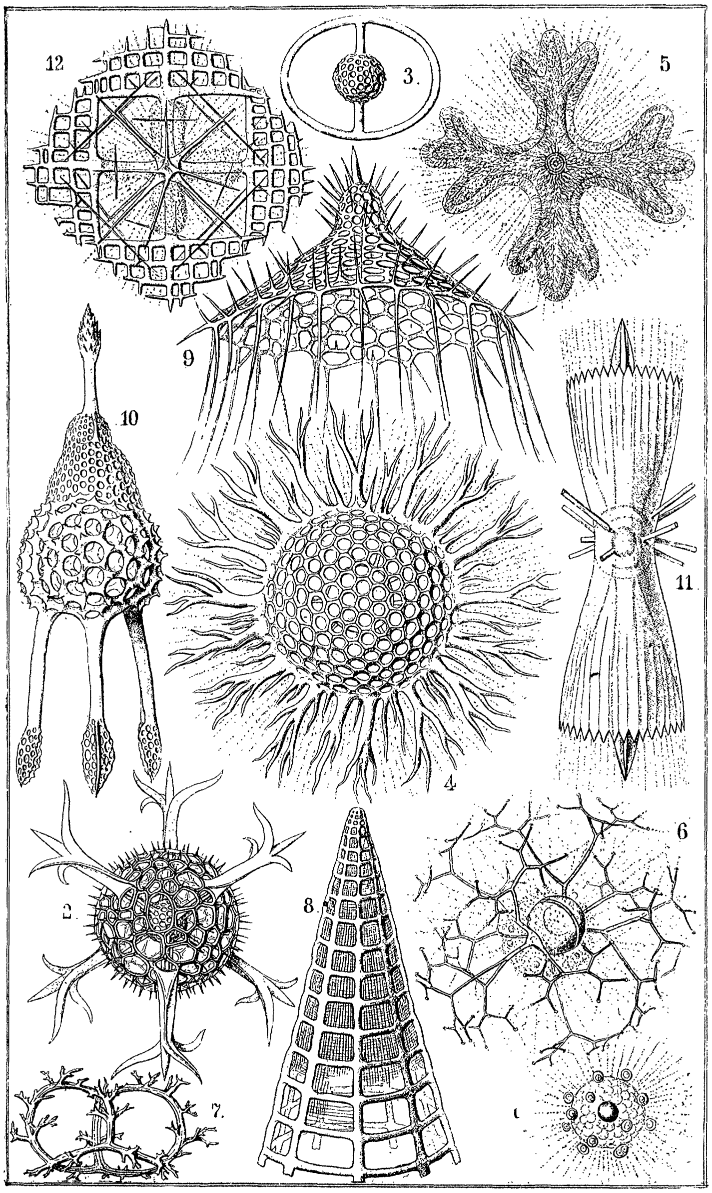
Much more generally interesting than the Heliozoa and Mycetozoa are the last two divisions of the Rhizopods, the classes of the lime-shelled *Thalamaria* and the flint-shelled *Radiolaria*. The extremely neat and variously shaped shells of these Rhizopods, after the death of the one-celled soft body, fall to the bottom of the sea and cover the ground there in enormous accumulations of slimy substance. The great geological importance of this Protista-sediment, of the "calcareous slime" of the Globigerina, and the "flinty slime" of the Radiolaria, has become clear to us only during the last decade, since the discoveries made by the *Challenger* Expedition. The petrifaction of this slime and its subsequent upheaval might give rise to mighty mountain masses.

As early as the middle of last century (since 1731) it was known that the ocean sand on many shores consisted of accumulations of minute calcareous shells; and on account of their striking resemblance to the calcareous shells of snails and cuttle-fish (Nautilus) they were regarded as the former habitations of minute molluscs. It was not till 1835 that Dujardin pointed out that the living inhabitants of these variously formed shells were not highly organized animals, but simple corpuscles of slime, lumps of plasma or sarcode, from the outer surfaces of whose bodies radiate fine threads. Sometimes their simple cell-substance encloses but one large kernel, sometimes several. Their natural

history is now very accurately known, and the class is generally called (very inappropriately) *Foraminifera;* a better name would be *Thalamaria,* or *Thalamophora.* In spite of the simple nature of their bodies, these little chambered animalcules, nevertheless, secrete a firm shell of calcareous earth, presenting a great variety of neat shapes. In the earlier and simpler Thalamaria, the shell is a simple chamber, bell-shaped, tubular, or like a snail's; from the mouth proceeds a bunch of mucous threads. In contradistinction to these *single-chambered forms* (Monothalamia), the *many-chambered forms* (Polythalamia)—to which the great majority belong—possess a house consisting of numerous little chambers arranged in a very artistic manner. These chambers sometimes lie in a row one behind the other, sometimes in concentric circles or spirals, in the form of a ring round a central point, and then frequently one above the other in a number of tiers, like the boxes of a large amphitheatre. This formation, for example, is found in the nummulites, whose calcareous shells, of the size of a lentil, have accumulated to the number of millions, and form whole mountains on the shores of the Mediterranean. The stones of which some of the Egyptian pyramids are built consist of such nummulitic limestone. In most cases the chambers of the shells of the Polythalamia are wound round one another in a spiral line. The chambers are connected with one another by passages and doors, like rooms of a large palace, and are generally open towards the outside by numerous little windows, out of which the plasmic body can stream or strain forth its little pseudo-feet, or rays of slime, which are always changing form. But in spite of the exceedingly complicated and elegant structure of this

PLATE XVI.

DEEP-SEA RADIOLARIA OF THE *CHALLENGER*.



calcareous labyrinth, in spite of the endless variety in the structure and the decoration of its numerous chambers, and in spite of the regularity and elegance of their execution, the whole of this artistic palace is found to be the secreted product of a perfectly formless, slimy mass, devoid of any component parts! Verily, if the whole of the recent anatomy of animal and vegetable textures did not support our theory of plastids, if all its important results did not unanimously corroborate the fact that the whole miracle of vital phenomena and vital forms is traceable to the active agency of formless protoplasm, the Polythalamia alone would secure the triumph of that theory. For we may here at any moment, by means of the microscope, point out the wonderful fact, first established by Dujardin and Max Schultze, that the formless mucus of the albuminous plasma-body is able to secrete the neatest, most regular, and most complicated of structures. And this is simply the result of *inheritance* and *adaptation;* it further teaches us how this same "primæval slime," this same protoplasm, can produce in the bodies of animals and plants the most different and complex cellular forms.

A higher stage of development is attained by the one-celled organisms of the last class of the Protista, the wonderful *Radiolaria* (Plates XV. and XVI.). The cell-substance here separates into an inner central capsule (with kernel) and an outer gelatinous membrane (Calymma). The globular, disc-shaped, or longish "central capsule" is enclosed in a mucus-layer of plasma, from which radiate thousands of extremely fine threads, the branching and confluent, so-called, pseudo-feet. Between these are scattered numerous yellow cells of unknown function, containing grains of

starch—the symbiotic Xanthelleæ which we spoke of above among the Palmellaria (compare p. 78 and Fig. 17 *l*). Most Radiolaria are characterized by a highly developed skeleton,

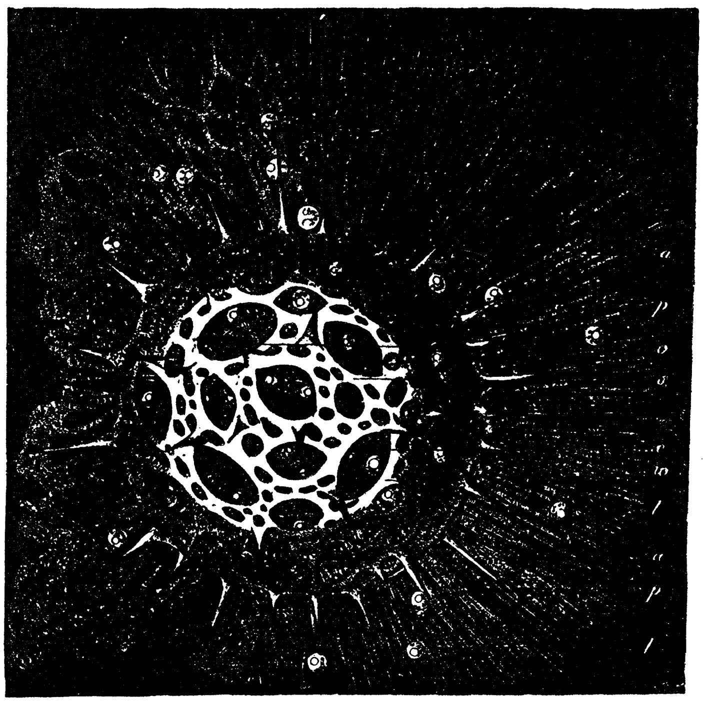


FIG. 17.—Cyrtidosphæra echinoides, 400 times enlarged. *c.* Globular central capsule. *s.* Trellis-work of the perforated flinty shell. *a.* Radial spikes, radiating from the latter. *p.* Pseudo-feet radiating from the mucous covering surrounding the central capsule. *l.* Yellow globular cells, scattered between the latter, containing grains of Amylum (Zooxanthellæ).

which consists of flint, and displays a wonderful richness of the neatest and most curious forms (compare Plates XV. and XVI. with explanation). Sometimes this flinty skeleton

forms a simple trellis-work ball (Fig. 17 *s*), sometimes a marvellous system of several concentric trellised balls, encased in one another, and connected by radial rods (Spumellaria). In most cases delicate spicules, which are frequently branched like a tree, radiate from the surface of the balls. In other cases the whole skeleton consists of only one flinty star, and is then generally composed of twenty rods, distributed according to definite mathematical laws and united in a common central point (Acantharia). The skeletons of other Radiolaria again form symmetrical, many-chambered structures, as in the case of the Polythalamia (Nassellaria). Many even possess bivalved, neatly trellised shells like mussels (Phæodaria). No other groups of organisms develop in the formation of their skeletons such an amount of different fundamental forms, such geometrical regularity, and such elegant architecture. One of the simplest forms is the *Cyrtidosphæra echinoides* of Nice (Fig. 17). The skeleton in this case consists only of a simple trellised ball (*s*), with short radial spicules (*a*), which loosely surround the central capsule (*c*). Out of the mucous covering, enclosing the latter, radiate a great number of delicate little pseudopodia (*p*), which are partly drawn back underneath the shell, and fused into a lumpy mass of mucus. Between these are scattered a number of yellow cells (*l*).

The vital phenomena of the Radiolaria are no less interesting than the wonderful wealth of their neat little flinty shells. They take nourishment always by means of the confluent and retractile pseudopodia. Many species emit light in darkness; this phosphorescence proceeds from fatty globules contained in the central capsule. Propagation is effected by means of swarm-spores, by agile whip-cells which

originate in the central capsule. The general central principle of life, which is usually designated as *soul*, and which appears to be the general regulator of all the vital activities, is met with in the Radiolaria, as in all the other single-celled Protista, in its simplest form, as "cell-soul." (Compare my "General Natural History of the Radiolaria," Berlin, 1887, pp. 108–122.)

Several thousand neat little Radiolaria of the most varied forms are figured in my Monograph of this class and in the Report of the *Challenger* Expedition (see above, p. 55). Milliards of them live on the surface of the ocean, others swim about at the different depths. The memorable and eventful discoveries made by the *Challenger* Expedition a few years ago revealed the astonishing fact, that the slime at the bottom of the ocean and frequently at its deepest depths (some 27,000 feet) consists for the most part of Radiolaria. And recently Dr. Rüst has pointed out that many stones (for instance, opals and flints) consist of fossilized Radiolaria shells baked together. Sometimes their fossilized shells are found accumulated in such masses that in many places whole mountains are formed of them; for example, the Nicobar Islands in the Indian Archipelago, and the Island of Barbadoes in the Antilles. Hence in this wonderful class of Protista we have a proof of the old proverb, that "*Nature is greatest in the smallest things*" ("Natura in minimis maxima").

SYSTEMATIC SURVEY OF THE KINGDOM OF PRIMÆVAL PLANTS.

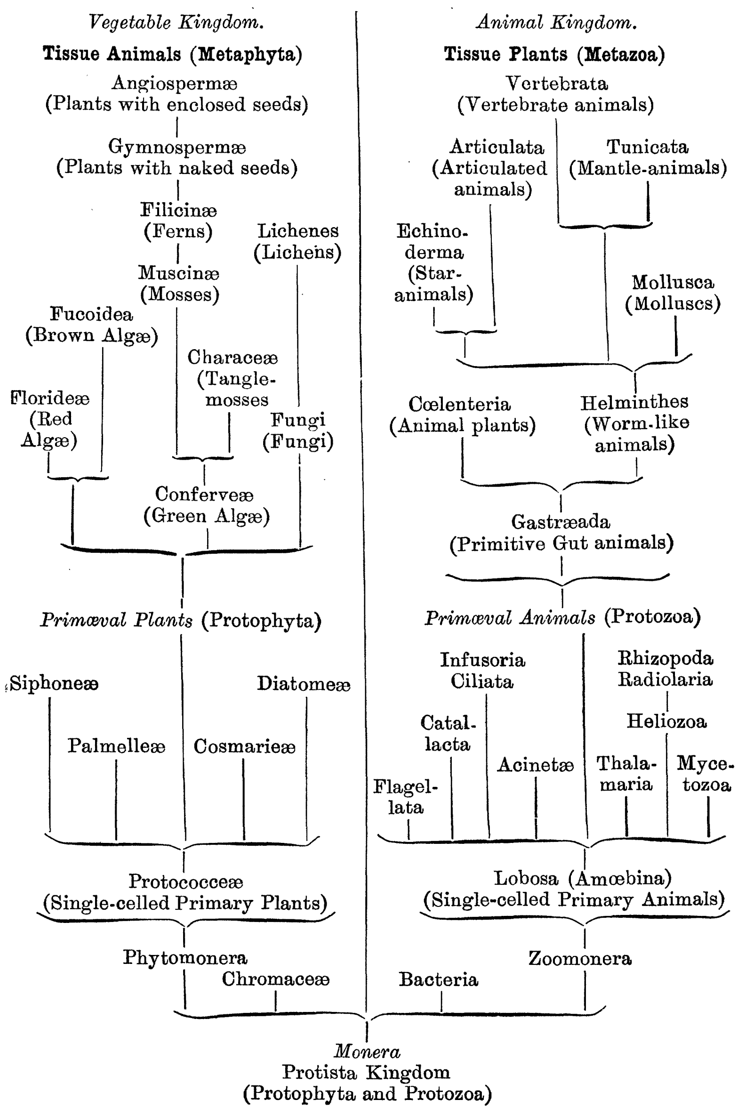
Protophyta (Protista Vegetalia). Single-celled Organisms with Phytoplasma (Reducing-plasma).

Classes.	*Class-character.*	*Orders.*	*Example.*
I. *Phytarcha.* Primæval Plants without cell-kernel (Phytocytoda).	1 A. *Phytomonera,* cytods without membrane	1. Probiontes.	Archibion.
	1 B. *Chromaceæ,* cytods with cellular membrane	2. Chroococceæ. 3. Nostochineæ.	Chroococcus. Nostoc.
II. *Diatomeæ.* (Auxosporeæ.)	Cell with bivalved flinty-shell; propagates by division	1. Coocochromia. 2. Placochromia.	Melosira. Navicula.
III. *Cosmariæ.* (Desmidieæ.)	Cell with bifid cellular covering; propagates by division	1. Closteriaceæ. 2. Desmidiaceæ.	Euastrum. Desmidium.
IV. *Palmellariæ.* (Palmellaceæ.)	Cell with simple (generally globular or roundish) cellular covering; propagates by swarm-spores	1. Protococceæ. 2. Xanthelleæ. 3. Calcocyteæ.	Protococcus. Zooxanthella. Rhabdosphæra.
V. *Siphoneæ.* (Cœloblastæ.)	Cell very large, imitating the form of higher plants, with numerous kernels (Pseudocormus)	1. Botrydiaceæ. 2. Codiacea. 3. Caulerpaceæ.	Botrydium. Codium. Caulerpa.

SYSTEMATIC SURVEY OF THE KINGDOM OF PRIMÆVAL ANIMALS.

Protozoa (Protista Animalia). Single-celled Organisms with Zooplasm (Oxidizing-plasma).

Main Classes.	*Classes.*	*Orders.*	*Example.*
I. *Zoarcha.* Primæval animals without cell-kernel (Zoocytoda).	1. *Zoomonera,* with Pseudopodia	1. Lobomonera. 2. Rhizomonera.	Protamœba. Protomyxa.
	2. *Bacteria,* without Pseudopodia	1. Sphærobacteria. 2. Rhabdobacteria.	Micrococcus. Bascillus.
II. *Cytarcha.* Simplest single-celled animals with or without little lobed feet.	3. *Lobosa* (Amœbina), cells with little lobed feet	1. Gymnolobosa. 2. Thecolobosa.	Amœba. Arcella.
	4. *Gregarinæ* (Sporozoa), cells without lobed feet	1. Monocystida. 2. Polycystida.	Monocystis. Didymophyes.
III. *Infusoria.* (Infusion-animalcules.) Single-celled animals with ciliary movements (with whips or flimmer-hairs).	5. *Flagellata* (Mastigophora) (Whip-cells), cells with flagellum	1. Mastigiata. 2. Catallacta. 3. Dinoflagellata. 4. Cystoflagellata.	Euglena. Magosphæra. Peridinium. Noctiluca.
	6. *Ciliata* (fringed cells), cells with vibrating hairs	1. Holotricha. 2. Heterotricha. 3. Hypotricha. 4. Petritricha.	Paramæcium. Stentor. Euplotes. Vorticella.
	7. *Acinetæ* (Suctoria), cells with sucking-tubes	1. Monocinetæ. 2. Synacinetæ.	Podophrya. Dendrosoma.
IV. *Rhizopoda.* (Sarcodina.) Root-footers. Single-celled animals with root-feet or pseudopodia (Reticularia).	8. *Mycetozoa* (Myxomycetes), with spore-bladder	1. Physareæ. 2. Lycogleæ.	Æthalium. Lycogala.
	9. *Heliozoa,* with medullary substance	1. Aphrothoraca. 2. Chalarothoraca. 3. Desmothoraca.	Actinophrys. Acanthocystis. Hedriocystis.
	10. *Thalamaria* (Foraminifera), without central capsule	1. Monostegia. 2. Polystegia. 3. Monothalamia. 4. Polythalamia.	Gromia. Miliola. Lagena. Polystomella.
	11. *Radiolaria,* with central capsule	1. Spumellaria. 2. Acantharia. 3. Nassellaria. 4. Phæodoria.	Haliomma. Dorataspis. Podocyrtis. Aulosphæra.


Vegetable Kingdom.
Tissue Animals (Metaphyta)
Angiospermæ
(Plants with enclosed seeds)
Gymnospermæ
(Plants with naked seeds)
Filicinæ
(Ferns)
Lichenes
(Lichens)
Muscinæ
(Mosses)
Fucoidea
(Brown Algæ)
Characeæ
(Tangle-
mosses
Florideæ
(Red
Algæ)
Fungi
(Fungi)
Conferveæ
(Green Algæ)
Primæval Plants (Protophyta)
Siphoneæ
Diatomeæ
Palmelleæ
Cosmarieæ
Protococceæ
(Single-celled Primary Plants)
Phytomonera
Chromaceæ
Animal Kingdom.
Tissue Plants (Metazoa)
Vertebrata
(Vertebrate animals)
Articulata
(Articulated
animals)
Tunicata
(Mantle-animals)
Echino-
derma
(Star-
animals)
Mollusca
(Molluscs)
Cœlenteria
(Animal plants)
Helminthes
(Worm-like
animals)
Gastræada
(Primitive Gut animals)
Primæval Animals (Protozoa)
Infusoria
Ciliata
Rhizopoda
Radiolaria
Heliozoa
Catal-
lacta
Acinetæ
Thala-
maria
Myce-
tozoa
Flagel-
lata
Lobosa (Amœbina)
(Single-celled Primary Animals)
Bacteria
Zoomonera
Monera
Protista Kingdom
(Protophyta and Protozoa)

CHAPTER XIX.

PEDIGREE AND HISTORY OF THE VEGETABLE KINGDOM.

The Natural System of the Vegetable Kingdom.—Division of the Vegetable Kingdom into Six Branches and Eighteen Classes.—The Sub-kingdom of Flowerless Plants (Cryptogamia).—Primary Group of the Thallus Plants.—Derivation of the Metaphyta von Protophyta.—The Tangles, or Algæ (Primary Algæ, Green Algæ, Brown Algæ, Red Algæ, Moss Algæ).—The Thread-plants, or Inophytes (Lichens and Fungi).—Symbiosis.—Primary Group of the Prothallus Plants (Mesophyta or Prothallophyta).—The Mosses, or Muscinæ (Liverworts, Leaf-mosses).—The Ferns, or Filicinæ (Leaf-ferns, Bamboo-ferns, Water-ferns, Scale-ferns).—Sub-kingdom of Flowering Plants (Phanerogamia).—The Gymnosperms, or Plants with Naked Seeds (Palm-ferns = Cycadeæ; Pines = Coniferæ). — Meningos (Gnetaceæ). — The Angiosperms, or Plants with Enclosed Seeds.—Monocotylæ.—Dicotylæ.—Cup-blossoms (Apetalæ).—Star-blossoms (Choripetalæ).—Bell-flowers (Gamopetalæ). The Historical Stages of the Main Groups of the Vegetable Kingdom as a Proof of Transformism.

EVERY attempt that we make to gain a knowledge of the pedigree of any small or large group of kindred organisms must, in the first instance, start with the evidence afforded by the existing "*natural system*" of this group. For although the natural system of animals and plants will never become finally settled, but will always represent a merely approximate knowledge of true relationship, still it will always possess great importance as a hypothetical pedigree. It is true, by a "natural system" most zoologists and botanists only endeavour to express in a concise way

the subjective conceptions which each has of the objective "*form-relationships*" of organisms. These form-relationships, however, as the reader has seen, are in reality the necessary result of true *blood-relationship.* Consequently, every morphologist, in promoting our knowledge of the natural system, at the same time promotes our knowledge of the pedigree, whether he wishes it or not. The more the natural system deserves its name, and the more firmly it is established upon the concordance of results obtained from the study of comparative anatomy, ontogeny, and palæontology, the more surely may we consider it as the approximate expression of the true pedigree of the organic world.

In entering upon the task contemplated in this chapter, the genealogy of the vegetable kingdom, we shall have, according to this principle, first to glance at the *natural system of the vegetable kingdom* as it is at present (with more or less important modifications) adopted by most botanists. According to the system generally in vogue, the whole series of vegetable forms is divided into two main groups. These main divisions, or sub-kingdoms, are the same as were distinguished a hundred and fifty years ago by Charles Linnæus, the founder of systematic natural history, and were called by him *Cryptogamia,* or secretly-blossoming plants, and *Phanerogamia,* or openly-flowering plants. The latter, Linnæus, in his artificial system of plants, divided, according to the different number, formation, and combination of the anthers, and also according to the distribution of the sexual organs, into twenty-three different classes, and then added the Crytogamia to these as the twenty-fourth and last class.

The *Cryptogamia,* the secretly-blossoming or flowerless plants, which were formerly but little observed, have in consequence of the careful investigations of recent times been proved to present such a great variety of forms, and such a marked difference in their coarser and finer structure, that we must distinguish no less than thirteen different classes of them; whereas the number of classes of flowering plants, or *Phanerogamia,* may be limited to five. However, these *eighteen classes of the vegetable kingdom* can again be naturally grouped in such a manner that we are able to distinguish in all *six main divisions* or *branches* of the vegetable kingdom. Two of these six branches belong to the flowering, and four to the flowerless plants. The table on p. 110 shows how the eighteen classes are distributed among the six branches, and how these again fall under the *sub-kingdoms* of the vegetable kingdom.

The one sub-kingdom of the *Cryptogamia* may now be naturally divided into *two* main divisions, or primary groups, differing very essentially in their internal structure and in their external form, namely, the Thallus plants and the Prothallus plants. The group of *Thallus plants* comprises the two large branches of Tangles, or Algæ, which live in water, and the Fungi, which grow on land, on the earth and upon decaying bodies, etc. The group of *Prothallus plants,* on the other hand, comprises the two branches of Mosses and Ferns, containing a great variety of forms.

All *Thallus plants,* or *Thallophytes,* can be directly recognized from the fact that the two morphological fundamental organs of all other plants, stem and leaves, cannot be distinguished in their structure. The complete body of all

Algæ and of all Fungi is a mass composed of simple cells, which is called a *lobe*, or *thallus*. This thallus is as yet not differentiated into axial organs (stem and root) and leaf-organs. On this account, as well as through many other peculiarities, the Thallophytes contrast strongly with all remaining plants—those comprised under the two sub-kingdoms of Prothallus plants and Flowering plants—and for this reason the two latter sub-kingdoms are frequently classed together under the name of *Stemmed plants* or *Cormophytes*. The following table will explain the relation of these three sub-kingdoms to one another according to the two different views:—

I. Flowerless Plants (*Cryptogamia*)	A. Thallus Plants (*Thallophyta*)	I. Thallus Plants (*Thallophyta*)
	B. Prothallus Plants (*Prothallophyta*)	II. Stemmed Plants (*Cormophyta*)
II. Flowering Plants (*Phanerogamia*)	C. Flowering Plants (*Phanerogamia*)	

The stemmed plants, or Cormophytes, in the organization of which the difference of axial-organs (stem and root) and leaf-organs is already developed, form at present, and have, indeed, for a very long period formed, the principal portion of the vegetable world. However, this was not always the case. In fact, stemmed plants, not only of the flowering group, but even of the prothallus group, did not exist at all during that immeasurably long space of time which forms the beginning of the first great division of the organic history of the earth, under the name of the archilithic, or primordial period. The reader will recollect that during this period the Laurentian, Cambrian, and Silurian systems

of strata were deposited, the thickness of which, taken as a whole, amounts to about 70,000 feet. Now, as the thickness of all the more recent superincumbent strata, from the Devonian to the deposits of the present time, taken together, amounts to only about 60,000 feet, we were enabled from this fact alone to draw the conclusion—which is probable also for other reasons—that the archilithic, or primordial, period was of longer duration than the whole succeeding period down to the present time. During the whole of this immeasurable space of time, which probably comprises many millions of centuries, vegetable life on our earth seems to have been represented exclusively by the primary group of Thallus plants, and, moreover, only by the main class of marine Thallus plants, that is to say, the Algæ. At least all the petrified remains which are positively known to be of the primordial period belong exclusively to this main class. Recently, however, some remains of land-inhabitants (ferns and scorpions) have been discovered in the Silurian system. But as nearly all the animal remains of this immense period belong exclusively to animals that lived in water, we come to the conclusion that for the greater part of that time organisms adapted to a life on land did not as yet exist.

For these reasons the first and most imperfect of the great main class of the vegetable kingdom, the division of the Algæ, or Tangles, must be of special interest to us. But, in addition, there is the interest which this group offers in another respect. In spite of the exceedingly simple composition of their homogeneous and but little differentiated cells, the Algæ show an extraordinary variety of different forms. To them belong the simplest and most

imperfect of all forms, as well as very highly developed and peculiar plants. The different groups of Algæ are distinguished as much by size of body as by the perfection and variety of their outer form. At the lowest stage we find such species as the minute little green Algæ and Thread-plants; at the highest stage the gigantic Macrocysts, which attain a length of from 300 to 400 feet, the longest of all forms in the vegetable kingdom. It is possible that a large portion of coal has been formed out of Algæ. If not for these reasons, yet the Algæ must excite our special attention from the fact that they form the beginning of vegetable life, and contain the original forms of all other groups of plants.

Most people living inland can form but a very imperfect idea of this exceedingly interesting branch of the vegetable kingdom, because they know only its comparatively small and simple representatives living in fresh water. The slimy green aquatic filaments and flakes of our pools and ditches and springs, the light green slimy coverings of all kinds of wood which have for any length of time been in contact with water, the yellowish green, frothy, and oozy growths of our village ponds, the green filaments resembling tufts of hair which occur everywhere in fresh water, stagnant and flowing, are for the most part composed of different species of Algæ. Incomparably grander are those classes of Algæ which may be seen by those who visit our sea-shores; we are there struck with wonder at the immense masses of cast-up seaweed, and on the rocky coast of the Mediterranean may be seen through the clear blue waters the beautifully formed and highly coloured vegetation of the Algæ at the bottom. And yet even these marine Algæ-forests of European

shores, so rich in forms, give only a faint idea of the colossal forests of Sargasso in the Atlantic Ocean, those immense banks of Algæ, covering a space of about 40,000 square miles—the same which made Columbus, on his voyage of discovery, believe that a continent was near. Similar but far more extensive forests of Algæ grew in the primæval ocean, probably in dense masses, and what countless generations of these archilithic Algæ have died out one after another is attested, among other facts, by the vast thickness of Silurian alum-schists in Sweden, the peculiar composition of which proceeds from those masses of submarine Algæ. According to the opinion of Frederick Mohr, a geologist of Bonn, even the greater part of our coal seams have arisen out of the accumulated dead bodies of the Algæ forests of the ocean.

Within the main division of Algæ we distinguish five different classes, namely: 1. Primæval Algæ, or Zygnemaceæ; 2. Green Algæ, or Conferveæ; 3. Brown Algæ, or Fucoideæ; 4. Red Algæ, or Florideæ; and 5. Moss Algæ, or Characeæ. Most botanists place at the head the group of *Primæval Plants* (Protophyta), those most simple and most imperfect of all plants, which we have already discussed as *vegetable Protista*. And undoubtedly those most ancient vegetable organisms, from which all other plants are derived, belong to these Protophyta. Still, for reasons already given, it seems more appropriate to contrast these "single-celled plants" with the Metaphyta, as the tissue-forming many-celled plants (see above, p. 59). The fact of the two main groups being connected, and moreover by several transition-forms, cannot lead us astray in this idea. It is only a new proof of the theory of descent, and shows us the

phylogenetic manner in which "*tissue plants*" have originated from "*single-celled Algæ.*"

This *derivation of the Metaphyta from Protophyta is certain* from a polyphyletic point of view; *i.e.* different groups of many-celled Thallus plants (Algæ) have developed independently of one another out of several different groups of single-celled primæval plants. Thus, more especially the Primæval Algæ (Zygnemaceæ) arose out of the neat Cosmaria (the Closteriæ and Desmidiaceæ) which we have already discussed; both agree in the characteristic formation of the chlorophyll and in copulation, and are therefore classed together as "Conjugatæ." On the other hand, probably, the common green water hair-weeds (Confervaceæ), and the kindred leaf-formed water-lettuce (Ulvaceæ), have arisen out of a group of Siphoneæ, or out of an earlier primary group of the Palmellariæ common to both.

These and the next kindred groups of Algæ are now generally classed together as *Green Algæ* (Chlorophyceæ, or Conferveæ). They are all of a bright green colour, and, moreover, owing to the selfsame colouring matter, the leaf-green or chlorophyll, which also colours the leaves of all the higher plants green. To this class belong, besides a great number of low marine Algæ, most of the Algæ of fresh water, the common water hair-weeds, or Confervæ, the bright green water-lettuce, or Ulva, which resembles a very thin and long lettuce leaf, and also numerous small microscopic algæ, dense masses of which form a light green shiny covering to all sorts of objects lying in water—wood, stones, etc. These forms, however, rise above the simple primary Algæ in the composition and differentiation of their body. As the green Algæ, like the primæval Algæ, mostly

possess a very soft body, they are but rarely capable of being petrified. However, it can scarcely be doubted that these two class of Algæ were very fully developed in the Primordial period. Both probably peopled the fresh and salt waters of the earth in the greatest varieties, as early as the Laurentian period.

In the class of *Brown Tangles* (Fucoideæ), or *Black Algæ* (Phæophyceæ), the *branch* of the Algæ attains its highest stage of development, at least in regard to size and body. The characteristic colour of the Fucoid is more or less dark brown, sometimes tending more to an olive green or yellowish green, sometimes more to a brownish red or black colour.

Among these are the largest of all Algæ, which are at the same time the longest of all plants, namely, the colossal giant Algæ, amongst which the *Macrocystis pyrifera*, on the coast of California, attains a length of 400 feet. Also, among our indigenous Algæ, the largest forms belong to this group. Especially I may mention here the stately sugar-tangle (Laminaria), whose slimy, olive-green thallus-body, resembling gigantic leaves of from ten to fifteen feet in length, and from a half to one foot in breadth, are thrown up in great masses on the coasts of the North and Baltic Seas.

To this class belongs also the bladder-wrack (Fucus vesiculosus) common in our seas, whose fork-shaped, deeply cut leaves are kept floating on the water by numerous air-bladders (as is the case, too, with many other brown Algæ). The freely floating Sargasso Alga (*Sargassum bacciferum*), which forms the meadows or forests of the Sargasso Sea, also belongs to this class.

Although each individual of these large alga-trees is composed of many millions of cells, yet at the beginning of its existence it consists, like all higher plants, of a single cell—a simple egg. This egg—for example, in the case of our common bladder-wrack—is a naked, uncovered cell, and as such is so like the naked egg-cells of lower marine animals—for example, those of the Medusæ—that they might easily be mistaken one for another (Fig. 18). It is only the different chemical combination and the molecular structure of the plasma that determines the specific difference in the development.

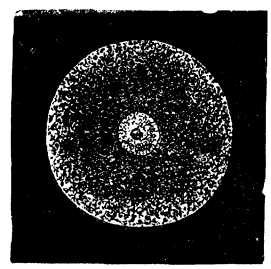


FIG. 18.—The egg of the common bladder-wrack (Fucus vesiculosus), a simple naked cell, much enlarged. In the centre of the naked globule of protoplasm the bright kernel is visible.

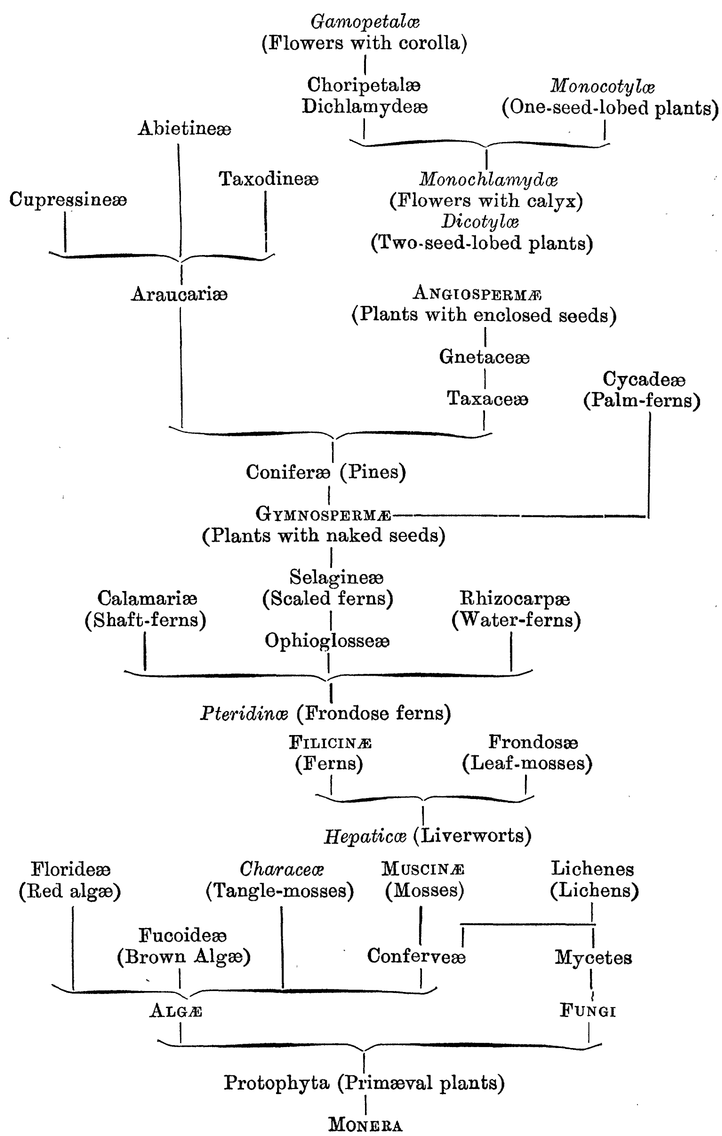
It was probably the Fucoideæ, or Brown Algæ, which during the primordial period, to a great extent, constituted the characteristic alga-forests of that immense space of time. Their petrified remains, especially those of the Silurian period, which have been preserved, can, it is true, give us but a faint idea of them, because the material of these Algæ, like that of most others, is ill suited for preservation in a fossil state. As has already been remarked, a large portion of coal is perhaps composed of them.

Less important is the fourth class of Algæ, that of the *Rose-coloured Algæ* (Rhodophyceæ), or *Red Sea-weeds* (Florideæ). This class, it is true, presents a great number of different forms; but most of them are of much smaller size than the Brown Algæ. Although they are inferior to

SYSTEMATIC SURVEY

Of the Six Branches and Eighteen Classes of the Vegetable Kingdom.

Primary Groups or Sub-Kingdoms of the Vegetable Kingdom.	*Branches or Clades of the Vegetable Kingdom.*	*Classes of the Vegetable Kingdom.*	*Systematic Name of the Classes.*
A. *Thallus Plants.* Thallota (Thallophyta).	I. *Algæ.* Tangles (Phycophyta).	1. Primæval algæ.	1. Zygnemaceæ.
		2. Green algæ.	2. Conferveæ.
		3. Brown algæ.	3. Fucoideæ.
		4. Red algæ.	4. Florideæ.
		5. Tangle-mosses.	5. Characeæ.
	II. *Fungi.* (Inophyta).	6. Sponge-fungi.	6. Mycetes.
		7. Lichens.	7. Lichenes.
B. *Prothallus Plants.* Prothallota (Mesophyta).	III. *Muscinæ.* Mosses (Bryophyta).	8. Liverworts.	8. Hepaticæ. (Thallobrya)
		9. Frondose mosses.	9. Frondosa. (Phyllobrya)
	IV. *Filicinæ.* Ferns (Pteridophyta).	10. Frondose ferns.	10. Pteridinæ. (Filices)
		11. Aquatic ferns.	11. Rhizocarpeæ. (Hydropterides)
		12. Reed-ferns.	12. Calamariæ. (Equisetinæ)
		13. Scale-ferns.	13. Selagineæ. (Lycopodinæ)
C. *Flowering Plants.* Phanerogamæ (Anthophyta).	V. Plants with naked seeds (*Gymnospermæ*).	14. Palm-ferns.	14. Cycadeæ.
		15. Pines.	15. Coniferæ.
		16. Meningos.	16. Gnetaceæ.
	VI. Plants with enclosed seeds (*Angiospermæ*).	17. Plants with one seed lobe.	17. Monocotylæ.
		18. Plants with two seed lobes.	18. Dicotylæ.


Gamopetalæ
(Flowers with corolla)
Choripetalæ
Dichlamydeæ
Monocotylæ
(One-seed-lobed plants)
Abietineæ
Taxodineæ
Cupressineæ
Monochlamydæ
(Flowers with calyx)
Dicotylæ
(Two-seed-lobed plants)
Araucariæ
ANGIOSPERMÆ
(Plants with enclosed seeds)
Gnetaceæ
Taxaceæ
Cycadeæ
(Palm-ferns)
Coniferæ (Pines)
GYMNOSPERMÆ
(Plants with naked seeds)
Selagineæ
(Scaled ferns)
Calamariæ
(Shaft-ferns)
Rhizocarpæ
(Water-ferns)
Ophioglosseæ
Pteridinæ (Frondose ferns)
FILICINÆ
(Ferns)
Frondosæ
(Leaf-mosses)
Hepaticæ (Liverworts)
Florideæ
(Red algæ)
Characeæ
(Tangle-mosses)
MUSCINÆ
(Mosses)
Lichenes
(Lichens)
Fucoideæ
(Brown Algæ)
Conferveæ
Mycetes
ALGÆ
FUNGI
Protophyta (Primæval plants)
MONERA

the latter in perfection and differentiation, they far surpass them in some other respects. To them belong the most beautiful and elegant of all Algæ, which on account of the fine plumose division of their leaf-like bodies, and also on account of their pure and delicate red colour, are among the most charming of plants. The characteristic red colour sometimes appears as a deep purple, sometimes as a glowing scarlet, sometimes as a delicate rose tint, and may verge into violet and bluish purple, or on the other hand into brown and green tints of marvellous splendour. Whoever has visited one of our sea-coast watering-places must have admired the lovely forms of the Florideæ, which are frequently dried on white paper and offered for sale.

Most of the Red Algæ are so delicate that they are quite incapable of being petrified; this is the case with the splendid Ptilotes, Plocamia, Delesseria, etc. However, there are individual forms, like the Chondria and Sphærococca, which possess a harder thallus, often almost as hard as cartilage, and of these fossil remains have been preserved—principally in the Silurian, Devonian, and Carboniferous strata, and later in the Oolites. It is probable that this class also had an important share in the archilithic Algæ flora.

The fifth and last class of Algæ is formed by the *Tangle-mosses* (*Characeæ*). To these belong the candelabra-shaped plants (Chara) and the water-mosses (Nitella), whose green thread-like stalks, which twirl round the forked branches, often form dense beds in our ponds and pools. On the one hand, the Characeæ resemble the mosses both in anatomical structure and especially in their generative organs, and are nowadays classed directly beside them.

On the other hand, however, in many qualities they stand far below genuine Mosses, and appear more allied to the Green Algæ, or Confervæ. Hence they might be regarded as the survivors and peculiarly developed offshoots of those Green Algæ, out of which the true Mosses have originated. In many characteristics, moreover, the Characeæ are so very different from all other plants, that many botanists consider them a special main division of the vegetable kingdom.

As regards the relationship of the different classes of Algæ among one another and to other plants, the common root of the tribe is formed, in any case, by the *Primordial plants* (Protophyta), and not only of the different classes of Algæ, but of the whole vegetable kingdom. When organic life began by spontaneous generation, *Probiontes* only could have at first come into existence with particles of phytoplasm, or naked vegetable Monera. It is probable that, as early as the Laurentian period, these in the first place gave rise to enclosed cytods, by the naked, simple plasma-body of the Moneron forming a thickened crust on its surface or secreting a membrane. Subsequently, out of these encased cytods genuine vegetable-cells then arose, by a kernel or nucleus separating itself from the surrounding cell-substance, or cytoplasm. It is probable that our present single-celled Algæ (Cosmariæ, Palmellariæ, etc.) form but a small remnant of the rich kingdom of primordial plants which inhabited the Laurentian oceans. The three classes of Green Algæ, Brown Algæ, and Red Algæ are perhaps three different tribes, which arose independently of one another, from the common primary group of Protophyta, and which then developed further each in its own way, and

branched variously into orders and families. The Brown Algæ and Red Algæ have no closer relationship to the other classes of the vegetable kingdom. These other classes have developed out of the Green Algæ. It is probable, on the one hand, that the Mosses (out of which subsequently the ferns developed) originated out of a group of Green Algæ; the Fungi, on the other hand, may have originated directly out of the Protophyta. The Phanerogamæ, at all events, developed at a much later date out of the Ferns (compare p. 99).

The second main branch of the vegetable kingdom, as stated above, is formed by the Fungi, or Thread-plants (*Inophyta*). We understand by this term the two closely related classes of Fungi (Mycetes) and Lichens (Lichenes). Both classes differ from the other tissue-plants by their soft body being composed of a dense felt-work of very long, variously interwoven and peculiar threads or chains of cells —the so-called *hyphæ*. Both the structure and the growth of these hyphæ—which have no chlorophyll—as well as their mode of propagating, differ essentially from that of the other Metaphyta.

The genuine Fungi, or Mycetes, are in Germany called Sponges, and hence confounded with genuine animal sponges, or Spongiæ. But they stand in no relation to them whatever. On the other hand, they are closely allied to the lowest Algæ; the Algo-fungi, or Phycomycetes (the Saprolegniæ and Peronosporæ), in reality only differ from the bladder-wracks and Siphoneæ (the Vaucheria and Caulerpa) discussed above by the want of leaf-green or chlorophyll. On the other hand, all genuine Fungi show many peculiarities, and are strikingly different from most

other plants, more especially by their mode of taking food Other plants live mostly upon inorganic food, upon simple combinations which they render more complicated. They produce protoplasm by the combination of water, carbonic acid, and ammonia. They take in carbonic acid and give out oxygen. But the Fungi, like animals, live upon organic food, consisting of complicated combinations of carbon, which they receive from other organisms and assimilate. They inhale oxygen and give out carbonic acid like animals. They also never form leaf-green, or chlorophyll, which is so characteristic of most other plants. In like manner they never synthetically produce plasma, or starch. Hence many eminent botanists have repeatedly proposed to remove the Fungi completely out of the vegetable kingdom, and to regard them as a special and third kingdom, between that of animals and plants. The already mentioned close relationship between the Phycomycetes and the Siphoneæ (particularly the Saprolegniæ and Vaucheria) would make it seem likely that a portion of the Fungi are derived from them. By adaptation to a parasitical mode of life the phytoplasm of the Algæ became changed into the zooplasm of the Fungi; and this change of substance resulted in further most important transformations. It is probable that the different groups of Fungi arose polyphyletically out of different groups of Protophyta.

One of the most remarkable groups of plants, in a phylogenetic respect, is that of Lichens (*Lichenes*). The surprising discoveries of late years have taught us that every Lichen is really composed of two entirely distinct plants, of a low form of Alga (Nostochaceæ, Chroococcaceæ), and of a parasitic form of Fungus (Ascomycetes), which latter lives

as a parasite upon the former, and upon the nutritive substances prepared by it. The Algæ, on the other hand, receive shelter and protection from their parasitic friends. The relation is thus one of mutual benefit, and might more properly be termed a conjoint life (Symbiosis). Such Symbiontes are met with in many other classes (see p. 78). The green cells containing chlorophyll (Gonidia), which are found in every Lichen, belong to the Alga. But the colourless threads (*hyphæ*) which, densely interwoven, form the principal mass of the body of Lichens, belong to the parasitical Fungus. But in all cases the two forms of plants—Fungus and Alga—which are always considered as members of two quite distinct classes, are so firmly allied and so thoroughly interwoven, that every one looks upon a Lichen as a single organism. And, moreover, every Lichen has its own peculiar mode and form of growth.

Most Lichens form small, more or less formless or irregularly indented, crust-like coverings to stones, bark of trees, etc. Their colour varies through all possible tints, from the purest white to yellow, red, green, brown, and the deepest black. Many Lichens are important in the economy of nature from the fact that they can settle in the driest and most barren localities, especially on naked rocks upon which no other plant can live. The hard black lava, which covers many square miles of ground in volcanic regions, and which for centuries frequently presents the most determined opposition to the life of every kind of vegetation, is always first occupied by Lichens. It is the white or grey Lichens (Stereocaulon) which, in the most desolate and barren fields of lava, always begin to prepare the naked rocky ground for cultivation, and conquer it for subsequent higher vegeta-

tion. Their decaying bodies form the first mould in which mosses, ferns, and flowering plants can afterwards take firm root. Hardy Lichens are also less affected by the severity of climate than any other plants. Hence the naked rocks, even in the highest mountains—for the most part covered by eternal snow, on which no plant could thrive—are encrusted by the dry bodies of Lichens.

The second sub-kingdom of the vegetable kingdom is formed by the Prothallus plants (*Prothallota* or *Prothallophyta*), which by some botanists are called phyllogonic Cryptogamia (in contradistinction to the Thallus plants, or thallogonic Cryptogamia). They might also be called Middle plants (*Mesophyta*), inasmuch as, in a morphological and phylogenetic respect, they occupy a position midway between the lower Thallus plants and the higher flowering plants. This sub-kingdom comprises the two provinces of Mosses and Ferns.

Here we meet with (except in a few of the lowest forms) the separation of the vegetable body into two different fundamental organs, axial organs (stem and root) and leaves (or lateral organs). In this the Prothallus plants already resemble the Flowering plants, and hence the two groups have recently often been classed together as Stemmed plants, or Cormophytes. But, on the other hand, Mosses and Ferns resemble the Thallus plants, in the absence of the development of flowers and seeds, and even Linnæus classed them with these, as Cryptogamia, in contradistinction to the plants forming seeds or flowering plants (Anthophyta or Phanerogamia).

Under the name of "Prothallus plants" we combine the closely related Mosses and Ferns, because both exhibit

a peculiar and characteristic "alternation of generation" in the course of their individual development. For every species exhibits two different generations, of which the one is usually called the *Prothallium,* or *Fore-growth,* the other is spoken of as the *Cormus,* or actual *Stem* of the moss or fern. The first and original generation, the Fore-growth, or Prothallus, also called the Prothallium, or Protonema, still remains in that lower stage of elaboration manifested throughout life by all Thallus plants; that is to say, stem and leaf-organs have as yet not differentiated, and the entire cell-mass of the Fore-growth corresponds to a simple thallus. The second and more perfect generation of mosses and ferns—the Stem, or Cormus—on the other hand, develops a much more highly elaborate body, which has differentiated into stalk and leaf (as in the case of flowering plants), except in the lowest mosses, where this generation also remains in the lower stage of the thallus. With the exception of these latter forms, the first generation of Mosses and Ferns (the thallus-shaped Fore-growth) always produces a second generation with stem and leaves; the latter in its turn produces the thallus of the first generation, and so on. Thus, in this case, as in the ordinary cases of alternation of generation in animals, the first generation is like the third, fifth, etc., the second like the fourth, sixth, etc. (compare vol. i. p. 213).

Of the two main classes of Prothallus plants, the Mosses in general are at a much lower stage of development than the Ferns, and their lowest forms (especially in an anatomical respect) form the transition from the Thallus plants through the Algæ to Ferns. The genealogical connection of Mosses and Ferns which is indicated by this fact can, however, be

inferred only from the case of the most imperfect forms of the two classes; for the more perfect and higher groups of mosses and ferns do not stand in any close relation to one another, and develop in completely opposite directions. In any case Mosses have arisen directly out of Thallus plants, and probably out of Green Algæ. Ferns, on the other hand, are probably derived from extinct unknown Mosses, which were very nearly related to the lowest liverworts of the present day. In the history of creation, Ferns are of greater importance than Mosses.

The main class of *Mosses* (Muscinæ, or Bryophyta) contains the lower and more imperfect plants of the group of Mesophytes, which as yet do not possess vessels. Their bodies are mostly so tender and perishable that they are very ill suited for being preserved in a recognizable state as fossils. Hence the fossil remains of all classes of Mosses are rare and insignificant. It is probable that Mosses developed in very early times out of the Thallus plants, or, to be more precise, out of the Green Algæ. The Prothallus of many Mosses repeats even nowadays the form of the green hair-weeds, or Confervæ. In the primordial period there probably existed aquatic forms of transition from the latter to Mosses, and in the Silurian period transition-forms to those living on land. The Mosses of the present day—out of the gradually differentiating development of which comparative anatomy may draw some inferences as to their genealogy—are divided into two different classes, namely, Liverworts and Leafy Mosses.

The first and older class of Mosses, which is directly allied to the Green Algæ, or Confervæ, is formed by the *Liverworts* (Hepaticæ, or Thallobrya). The mosses belong-

ing to them are, for the most part, small and insignificant in form, but are pretty little plants. Their lowest forms still possess, in both generations, a simple thallus like the Thallus plants; as, for example, the Ricciæ and Marchantiaceæ. But the more highly developed liverworts, the Jungermanniaceæ and those akin to them, gradually commence to differentiate stem and leaf, and their most highly developed forms are closely allied to leaf-mosses. By this transitional series the liverworts show their direct derivation from the Thallophytes, and more especially from the Green Algæ.

Those Mosses, which are generally the only ones known to the uninitiated—and which, in fact, form the principal portion of the whole branch—belong to the second class, or *Leafy Mosses* (Musci frondosi, or Phyllobrya). Among them are most of those pretty little plants which, united in dense groups, form the bright glossy carpet of moss in our woods, or which, in company with liverworts and lichens, cover the bark of trees. As reservoirs, carefully storing up moisture, they are of the greatest importance in the economy of nature. Where man mercilessly cuts down and destroys forests, there, as a consequence, disappear the leafy mosses which covered the bark of the trees, or, protected by their shade, clothed the ground, and filled the spaces between the larger plants. Together with the leafy mosses disappear the useful reservoirs which stored up rain and dew for times of drought. Thus arises a disastrous dryness of the ground, which prevents the growth of any rich vegetation. In the greater part of Southern Europe—in Greece, Italy, Sicily, and Spain—mosses have been destroyed by the inconsiderate extirpation of forests, and

the ground has thereby been robbed of its most useful stores of moisture; once flourishing and rich tracts of land have been changed into dry and barren wastes. Unfortunately in Germany, also, this rude barbarism is beginning to prevail more and more. It is probable that the small frondose mosses have played this exceedingly important part in nature for a very long time, possibly from the beginning of the primary period. But as their tender bodies are as little suited as those of all other mosses for being preserved in a fossil state, palæontology can give us no information about this.

We learn from the science of petrifactions much more than we do in the case of Mosses, of the importance which the second branch of Prothallus plants—that is, Ferns—have had in the history of the vegetable world. Ferns, or, more strictly speaking, the "plants of the fern tribe" (Filicineæ, or Pterideæ, also called Vascular Cryptogams), formed during an extremely long period, namely, during the whole primary or palæolithic period, the principal portion of the vegetable world, so that we may without hesitation call it the *era of Fern Forests.* After the Silurian period, when some land-ferns (Eopteris) first appeared, that is during the deposits of the Devonian, Carboniferous, and Permian strata, plants like Ferns predominated so much over all others, that we are justified in giving this name to that period. In the stratifications just mentioned, but above all, in the immense layers of coal of the Carboniferous or Coal period, we find such numerous and occasionally well-preserved remains of Ferns, that we can form a tolerably vivid picture of the very peculiar land flora of the palæolithic period. In the year 1855 the total

number of the then known palæolithic species of plants amounted to about a thousand, and among these there were no less than 872 Ferns. Among the remaining 128 species were 77 Gymnosperms (pines and palm-ferns), 40 Thallus plants (mostly Algæ), and about 20 not accurately definable Cormophyta (stemmed plants).

As already remarked, Ferns probably developed out of the lower liverworts in the beginning of the Silurian period. In their organization Ferns rise considerably above Mosses, and in their more highly developed forms even approach the flowering plants. In Mosses, as in Thallus plants, the entire body is composed of almost equi-formal cells, little if at all differentiated; but in the tissues of Ferns we find those peculiarly differentiated strings of cells which are called the vessels of plants, and which are universally met with in flowering plants. Hence Ferns are sometimes united as "vascular Cryptogams" with Phanerogams, and the group so formed is called that of the "vascular plants" in contrast to the "cellular plants,"—*i.e.* to "cellular cryptogams" (Mosses and Thallus plants). This very important process in the organization of plants—the formation of vessels—first occurred, therefore, in the Silurian period, consequently in the beginning of the second and smaller half of the organic history of the earth. (Compare Plate XVII. and the explanation in the Appendix.)

The branch of Ferns, or Filicinæ, is divided into four distinct classes: (1) Frondose Ferns, or Pteridæ; (2) Reed Ferns, or Calamaria; (3) Aquatic Ferns, or Rhizocarpæ; (4) Scale Ferns, or Selaginæ. By far the most important of these four classes, and also the richest in forms, are first the Frondose Ferns, and then the Scale Ferns, which formed

the principal portion of the palæolithic forests. The Reed Ferns, on the other hand, had at that time already somewhat diminished in number; and of the Aquatic Ferns, we do not even know with certainty whether they then existed. It is difficult for us to form any idea of the very peculiar character of those gloomy palæolithic fern forests, in which the whole of the gay abundance of flowers of our present flora was entirely wanting, and which were not enlivened by any bird or mammal. (Compare Plate XVII.) Of the flowering plants there then existed only the two lowest classes, the Gymnosperms, pines and palm ferns, with naked seeds, whose simple and insignificant blossoms scarcely deserve the name of flowers.

The class among Ferns which has developed most directly out of the Liverworts is the class of real Ferns, in the narrow sense of the word, the *Frondose Ferns* (Filices, or Pteridæ, also called Phyllopterides). In the present flora of the temperate zones this class forms only a subordinate part for it is in most cases represented only by lower forms without trunks. But in the torrid zones, especially in the moist, steaming forests of tropical regions, this class presents us with the lofty palm-like *fern trees*. These beautiful tree-ferns of the present day, which form the chief ornament of our hot-houses, can however give us but a faint idea of the stately and splendid frondose ferns of the primary period, whose mighty trunks, densely crowded together, then formed entire forests. These trunks, accumulated in superincumbent masses, are found in the coal seams of the Carboniferous period, and between them, in an excellent state of preservation, are found the impressions of the elegant fan-shaped leaves, crowning the top of the trunk in

umbrella-like bush. The varied outlines and the feather-like forms of these fronds, the elegant shape of the branching veins or bunches of vessels in their tender foliage, can still be as distinctly recognized in the impressions of the palæolithic fronds as in the fronds of ferns of the present day. In many cases even the clusters of fruit, which are distributed on the lower surface of the fronds, are distinctly preserved. After the carboniferous period, the predominance of frondose ferns diminished, and towards the end of the secondary period they played almost as subordinate a part as they do at the present time.

The Calamariæ, Ophioglossæ, and Rhizocarpeæ seem to have developed as three diverging branches out of the Frondose Ferns, or Pteridæ. The Calamariæ, also Equisetinæ, or Calamophyta, have remained at the lowest stage of these three classes. They comprise three different orders, of which only one now exists, namely, the Horse-tails (Equisetaceæ). The two other orders, the Giant Reeds (Calamiteæ), and the Star-leaf Reeds (Asterophylliteæ), are long since extinct. All Calamariæ are characterized by a hollow and jointed stalk, stem, or trunk, upon which the branches and leaves (in cases where they exist) are set so as to encircle the jointed stem in whorls. The hollow joints of the stalk are separated from one another by partition walls. In Horse-tails and Calamiteæ the surface is traversed by longitudinal ribs running parallel, as in the case of a fluted column, and the outer skin contains so much silicious earth in the living forms, that it is used for cleansing and polishing. In the Asterophylliteæ, the star-shaped whorls of leaves were more strongly developed than in the two other orders. There exist, at present, of the Calamariæ only

the insignificant Horse-tails (Equisetum), which grow in marshes and on moors; but during the whole of the primary and secondary periods they were represented by great trees of the genus Equisetites. A survivor of the giant Reed-trees still exists in Quito, in South America, the Equisetum giganteum. Among its nearest relatives were the Giant Reeds (Calamites), whose strong trunks grew to a height of about fifty feet. The order of Star-leaf Reeds, or Asterophyllites, on the other hand, contained smaller and prettier plants, of a very peculiar form, and belonged exclusively to the primordial period. (See Plate XVII. to the left.)

Among all Ferns, the history of the third class, that of the *Aquatic Ferns* (Rhizocarpeæ, or Hydropteridæ), is least known to us. In their structure these ferns, which live in fresh water, are on the one hand allied to the frond ferns, and on the other to the scaly ferns. Among them are the but little known moss ferns (Salvinia), clover ferns (Marsilea), and pill ferns (Pilularia) of our fresh waters; further, the large Azolla which floats in tropical ponds. Most of the aquatic ferns are of a delicate nature, and hence ill suited for being petrified. This is probably the reason of their fossil remains being so scarce, and of the oldest of those known to us having been found in the Jura system. It is probable, however, that the class is much older, and that it was already developed during the palæolithic period out of other ferns by adaptation to an aquatic life.

The special class of ferns is formed by the *Tongue Ferns* (Ophioglossæ, or Glossopterides). These ferns, to which belongs the Botrychium, as well as the Ophioglossum (adder's-tongue) of our native genera, were formerly considered as forming but a small subdivision of the frondose

ferns. But they deserve to form a special class, because they represent, phylogenetically, important transitional forms between the Pterideæ and the Lycopodinæ, and must be regarded as among the direct progenitors of the flowering plants.

The last highly developed class is formed by the *Scale Ferns* (Lycopodinæ, Lepidophytes, or Selagines). In the same way as the Ophioglossæ arose out of the frondose forms, the scale ferns arose out of the Ophioglossæ. They were more highly developed than all other ferns, and form the transition to flowering plants, which must have developed out of them. Next to the frondose ferns they took the largest part in the composition of the palæolithic fern forests. This class also contains, as does the class of reed ferns, three nearly related but still very different orders, of which only one now exists, the two others having become extinct towards the end of the carboniferous period. The scaled ferns still existing belong to the order of the club-mosses (Lycopodiaceæ). They are mostly small, pretty moss-like plants, whose tender, many-branched stalk creeps in curves on the ground like a snake, and is densely encompassed and covered by small scaly leaves. The pretty creeping Lycopodium of our woods, which mountain tourists twine round their hats, is known to all, as also the still more delicate Selaginella, which under the name of creeping moss is used to adorn the soil of our hot-houses in the form of a thick carpet. The largest *club-mosses* of the present day are found in the Sunda Islands, where their stalks rise to the height of twenty-five feet, and attain half a foot in thickness. But in the primary and secondary periods even larger trees of this kind were widely distributed, the most

ancient of which probably were the progenitors of the pines (Lycopodites). The most important dimensions were, however, attained by the class of scale trees (Lepidodendreæ), and by the seal trees (Sigillarieæ). These two orders, with a few species, appear in the Devonian period, but do not attain their immense and astonishing development until the Carboniferous period, and become extinct towards the end of it, or in the Permian period directly following upon it. The scale trees, or Lepidodendreæ, were probably more closely related to club-mosses than to Sigillarieæ. They grew into splendid, straight, unbranching trunks which divided at the top into numerous forked branches. They bore a large crown of scaly leaves, and like the trunk were marked in elegant spiral lines by the scars left at the base of the leaf-stalks which had fallen off (see Plate XVII. above on the right). We know of scale-marked trees from forty to sixty feet in length, and from twelve to fifteen feet in diameter at the root. Some trunks are said to be even more than a hundred feet in length. In the coal are found still larger accumulations of the no less highly developed but more slender trunks of the remarkable seal trees (Sigillarieæ), which in many places form the principal part of coal seams. Their roots were formerly described as quite a distinct vegetable form (under the name of Stigmaria). The Sigillarieæ are in many respects very like the scale-trees, but differ from them and from ferns in general in many ways. They were possibly closely related to the extinct Devonian *Lycopterideæ,* combining characteristic peculiarities of the club-mosses and the frondose ferns, which Strasburger considers as the hypothetical primary form of flowering plants.

In leaving the dense forests of the primary period, which were principally composed of frond ferns (Lepidodendreæ and Sigillarieæ), we pass onwards to the no less characteristic pine forests of the secondary period. Thus we leave the domain of the Cryptogamia, the plants forming neither flowers nor seeds, and enter the second main division of the vegetable kingdom, namely, the sub-kingdom of the *Phanerogamia, flowering plants* forming seeds (recently, also, often called Anthophyta or Spermaphyta). This division, so rich in forms, containing the principal portion of the present vegetable world, and especially the majority of plants living on land, is certainly of a much more recent date than the division of Cryptogamia. For it can have developed out of the latter only during the course of the palæolithic period. We can with full assurance maintain that, during the whole archilithic period, hence during the first and longer half of the organic history of the earth, no flowering plants as yet existed, and that they first developed during the primary period out of Cryptogamia of the fern kind. The anatomical and embryological relation of Phanerogamia to the latter is so close, that from it we can with certainty infer their genealogical connection, that is, their true relationship. Flowering plants cannot have directly arisen out of thallus plants, nor out of mosses; but only out of ferns, or Pteridophyta. Most probably the scaled ferns, or Selagines, and more especially amongst these the Lycopterideæ, forms closely related to the Selaginella of the present day, have been the direct progenitors of the Phanerogamia.

On account of its anatomical structure and its embryological development, the sub-kingdom of the Phanerogamia

PLATE XVII.

FERN FOREST OF THE COAL PERIOD.

has for a long time been divided into two large branches; into the *Gymnosperms*, or plants with naked seeds, and the *Angiosperms*, or plants with enclosed seeds. The latter are in every respect more perfect and more highly organized than the former, and developed out of them only at a late date during the secondary period. The Gymnosperms, both anatomically and embryologically, form the transition group from Ferns to Angiosperms. In the characteristic formation of the Archegonia (or female sexual organs), the three main groups of the Gymnosperms, Ferns, and Mosses show such a striking resemblance, that many naturalists have recently classed them together as Archegoniata.

The lower and older of the two main classes of flowering plants, that of the *Gymnospermæ* (with naked seeds), attained its most varied development and widest distribution during the mesolithic or secondary epoch. It was no less characteristic of this period, than was the fern group of the preceding primary, and the Angiosperms of the succeeding tertiary, epoch. Hence we might call the secondary epoch that of Gymnosperms, or after its most important representatives, the era of Pine Forests. The Gymnosperms are divided into three classes: the Coniferæ, Cycadeæ, and Gnetaceæ. We find fossil remains of these even in the Devonian period, and must infer from this that the transition from scaled ferns to Gymnosperms took place during the first division of the Palæozoic period. However, the Gymnosperms play but a very subordinate part during the whole of the succeeding primary epoch, and do not predominate over Ferns until the beginning of the secondary epoch.

Of the three classes of Gymnosperms, that of the *Palm*

Ferns (Cycadeæ) stands at the lowest stage, and is directly allied to ferns, as the name implies, so that some botanists have actually included them in the fern group. In their external form they resemble palms, as well as tree ferns (or tree-like frond ferns), and are adorned by a crown of feathery leaves, which is placed either on a thick, short trunk, or on a slender, simple trunk like a pillar. At the present day this class, once so rich in forms, is but scantily represented by a few forms living in the torrid zones, namely, by the coniferous ferns (Zamia), the thick-trunked bread-tree (Encephalartos), and the slender-trunked Caffir bread-tree (Cycas). They may frequently be seen in hot-houses, and are generally mistaken for palms. A much greater variety of forms than occurs among the still existing palm ferns (Cycadeæ) is presented by the extinct and fossil Cycads, which occurred in great numbers more especially towards the middle of the secondary period, during the Jura, and which at that time principally determined the character of the forests.

The class of *Pines*, or *coniferous trees* (Coniferæ), has preserved down to our day a greater variety of forms than have the palm ferns. Even at the present time the trees belonging to it—cypresses, juniper trees, and trees of life (Thuja), the box and ginko trees (Salisburya), the araucaria and cedars, but above all the genus Pinus, which is so rich in forms, with its numerous and important species, spruces, pines, firs, larches, etc.—still play a very important part in the most different parts of the earth, and almost of themselves constitute extensive forests. Yet this development of pines seems but weak in comparison with the predominance which the class had attained over other plants

during the earlier secondary period, that of the Trias. At that time mighty coniferous trees—with but proportionately few genera and species, but standing together in immense masses of individuals—formed the principal part of the mesolithic forests. This fact justifies us in calling the secondary period the "era of the pine forests," although the remains of Cycadeæ predominate over those of coniferous trees in the Jura period.

The primary stock of the Coniferæ divided into two branches at an early period, into the Araucariæ on the one hand, and the Taxaceæ, or yew-trees, on the other. The majority of recent Coniferæ are derived from the former. Out of the latter the third class of the Gymnosperms—the Meningos, or Gnetaceæ—were developed. This small but very interesting class contains only three different genera—Gnetum, Welwitschia, and Ephedra; it is, however, of great importance, as it forms the transition group from the Coniferæ to the Angiosperms, and more especially to the Dicotyledons.

From the pine forests of the mesolithic, or secondary period, we pass on into the leafy forests of the cænolithic, or tertiary period, and we arrive thus at the consideration of the sixth and last class of the vegetable kingdom, that of the *Angiospermæ*, or *plants with enclosed seeds.* The first certain and undoubted fossils of plants with enclosed seeds are found in the strata of the chalk system, and indeed we here find, side by side, remains of the two classes into which the main class of Angiosperms is generally divided, namely, the *one seed-lobed plants*, or *monocotylæ*, and the *two-seed-lobed plants*, or *dicotylæ.* However, the whole group probably originated at an earlier period during the Trias. For

we know of a number of doubtful and not accurately definable fossil remains of plants from the Oolitic and Trias periods, which some botanists consider to be Angiosperms, whilst others consider them as Gymnosperms. In regard to the two classes of plants with enclosed seeds, the Monocotylæ and Dicotylæ, it is exceedingly probable that the Dicotyledons developed out of the Gnetaceæ, but that the Monocotyledons developed later out of a branch of the dicotyledons.

The class of *one-seed-lobed plants* (Monocotylæ, or Monocotyledons, also called Endogenæ) comprises those flowering plants whose seeds possess but one germ-leaf or seed-lobe (cotyledon). Each whorl of its flower contains in most cases *three* leaves, and it is very probable that the mother plants of all Monocotyledons possessed a regular triple blossom. The leaves are mostly simple, and traversed by simple, straight bunches of vessels or so-called "nerves." To this class belong the extensive families of the rushes, grasses, lilies, irids, and orchids, further a number of indigenous aquatic plants, the water-onions, sea-grasses, etc., and finally the splendid and highly developed families of the Aroideæ and Pandaneæ, the bananas and palms. On the whole, the class of Monocotyledons—in spite of the great variety of forms which it developed, both in the tertiary and the present period—is much more simply organized than the class of the Dicotyledons, and its history of development also offers much less of interest. Their fossil remains are rarely found well preserved; but at all events they existed in the chalk period, perhaps as early as the Trias period.

The second class of plants with enclosed seeds, the *two-*

seed-lobed (Dicotylæ, or Dicotyledons, also called Exogenæ), presents much greater historical and anatomical interest in the development of its subordinate groups. The flowering plants of this class generally possess, as their name indicates, *two* seed-lobes or germ-leaves (cotyledons). The number of leaves composing its blossom is generally not three, as in most Monocotyledons, but four, five, or a multiple of those numbers. Their leaves, moreover, are generally more highly differentiated and more composite than those of the Monocotyledons; they are traversed by crooked, branching bunches of vessels or "veins." To this class belong most of the leafed trees, and as they predominate in the tertiary period as well as, at present, over the Gymnosperms and Ferns, we may call the cænolithic period that of leafed forests.

Although the majority of Dicotyledons belong to the most highly developed and most perfect plants, still the lowest division of them is directly allied to the Gymnosperms, and particularly to the Gnetaceæ. In the lower Dicotyledons, as in the case of the Monocotyledons, calyx and corolla are as yet not differentiated. Hence they are called *Apetalous* (Monochlamydeæ, or Apetalæ). This sub-class must therefore doubtless be looked upon as the original group of the Angiosperms, and existed probably even during the Trias and Jura periods. Among them are most of the leafed trees bearing catkins—birches and alders, willows and poplars, beeches and oaks; further, the plants of the nettle kind—nettles, hemp, and hops, figs, mulberries, and elms; finally, plants like the spurges, laurels, and amaranth.

It was not until the chalk period that the second and more perfect sub-class of the Dicotyledons appeared, namely,

the *group with corollas* (Dichlamydeæ, or Corollifloræ). These arose out of the Apetalæ from the simple cover of the blossoms of the latter becoming differentiated into calyx and corolla. The sub-class of the Corollifloræ is again divided into two large main divisions or legions, each of which contains a large number of different orders, families, genera, and species. The first legion bears the name of star-flowers, or Choripetalæ; the second that of the bell-flowers, or Gamopetalæ.

The lower and less perfect of the two legions of the Corollifloræ are the star-flowers (also called Choripetalæ or Polypetalæ). To them belong the extensive families of the Umbelliferæ, or umbrella-worts (wild carrot, etc.), the Cruciferæ, or cruciform blossoms (cabbage, etc.); further, the Ranunculaceæ (buttercups) and Crassulaceæ, the Mallows and Geraniums, and, besides many others, the large group of Roses (which comprise, besides roses, most of our fruit trees), and the Pea-blossoms (containing, among others, beans, clover, genista, acacia, and mimosa). In all these Choripetalæ the blossom-leaves remain separate, and never grow together, as is the case in the Gamopetalæ. These latter developed first in the tertiary period out of the Choripetalæ, whereas the Choripetalæ appeared in the chalk period together with the Apetalæ.

The highest and most perfect group of the vegetable kingdom is formed by the second division of the Corollifloræ, namely, the legion of bell-flowers (Gamopetalæ or Monopetalæ). In this group the blossom-leaves, which in other plants generally remain separate, grow regularly together into a more or less bell-like, funnel-shaped, or tubular flower. To them belong, among others, the Bell-flowers and Con-

volvulus, Primroses and Heaths, Gentian and Honeysuckle, further the family of the Olives (olive trees, privet, elder, and ash), and finally, besides many other families, the extensive division of the Lip-blossoms (Labiatæ) and the Composites. In these last the differentiation and perfection of the Phanerogamic blossoms attain their highest stage of development, and we must therefore place them at the head of the vegetable kingdom, as the most perfect of all plants. In accordance with this, the legion of the Gamopetalæ appear in the organic history of the earth later than all the main groups of the vegetable kingdom—in fact, not until the cænolithic or tertiary epoch. In the earliest tertiary period the legion is still very rare, but it gradually increases in the mid-tertiary, and attains its full development only in the latest tertiary and the quaternary period.

Now if, having reached our own time, we look back upon the *whole history of the development of the vegetable kingdom,* we cannot but perceive in it a *grand confirmation of the Theory of Descent.* The two great principles of organic development which have been pointed out as the necessary results of natural selection in the Struggle for Life, namely, the laws of *differentiation* and *perfecting,* manifest themselves everywhere in the development of the larger and smaller groups of the natural system of plants. In each larger or smaller period of the organic history of the earth, the vegetable kingdom increases both in *variety* and *perfection.* During the whole of the long primordial period there existed only the lowest and most imperfect group, that of the Algæ. To these are added, in the primary period, the higher and more perfect Cryptogamia, especially

the main-class of Ferns. During the coal period the Phanerogamia begin to develop out of the latter; at first, however, they are represented only by the lower main-class, that of Gymnosperms. It was not until the secondary period that the higher main-class, that of Angiosperms, arose out of them. Of these also there existed at first only the lower groups without distinct corollas, the Monocotyledons and the Apetalæ. It was not until the chalk period that the higher Corollifloræ developed out of the latter. But even this most highly developed group is represented, in the chalk period, only by the lower stage of Star-flowers, or Choripetalæ, and only at quite a late date, in the tertiary period, did the more highly developed Bell-blossoms, Gamopetalæ, arise out of them, which at the same time are the most perfect of all flowering plants. Thus, in each succeeding later division of the organic history of the earth the vegetable kingdom gradually rose to a higher degree of perfection and variety.

The *exact phylogeny* of the orders and families in the *vegetable* kingdom, the knowledge of the primary relationships between the larger and smaller groups of every class, presents, on the one hand, much greater difficulties, and, on the other, is of far less interest than that of the *animal* kingdom. In the animal kingdom the variety in the division of labour and the change of form in the organs, the differentiation of the tissues, the wide divergence between the numerous classes, affords comparative morphology an inexhaustible domain full of the most interesting problems. The morphological differentiation of the vegetable kingdom cannot be compared with it. For even among the higher plants, the structure of the body is comparatively most

simple and the series of shapes uniform. All of the numberless forms of the Angiosperms seem only to be the variations of one theme, and differ from one another in a lesser degree than the manifold forms of one single class of animals, that of Insects.

CHAPTER XX.

PHYLOGENETIC CLASSIFICATION OF THE ANIMAL KINGDOM. THE GASTRÆA THEORY.

The Natural System of the Animal Kingdom.—The Earlier Systems of Linnæus and Lamarck.—The Four Types of Bär and Cuvier.—The Eight Types of Modern Zoology.—Their Genealogical Importance.—The Philosophy of Calcareous Sponges, the Homology of the Germ-layers and the Gastræa Theory.—Unity of the Tribes, or Phylæ.—Derivation of all Metazoa from the Gastræa.—The First Five Stages of Development of the Single-celled Animal Body.—The First Five Germinal Stages: Progeny-cell (Cytula), Mulberry-germ (Morula), Bladder-shaped Germ (Blastula), Hood-shaped Germ (Depula), Goblet-shaped Germ (Gastrula).—The Corresponding Five Primary Forms (Cytæa, Moræa, Blastæa, Depæa, Gastræa).—The Hollow Globule as the Primary Form of the Animal Body (Bär).—Cavity of the Intestine and Cavity of the Body.—The Cœlom Theory.—Pseudocœl and Enterocœl.—The Two Main Groups of Metazoa: I. Cœlentaria, or Cœlenterata (without body-cavity). II. Cœlomaria, or Bilaterata (with body-cavity).

THE natural system of organisms which we must employ in the animal as well as in the vegetable kingdom, as a guide in our genealogical investigations, is in both cases of but recent origin, and essentially determined by the progress of comparative anatomy and ontogeny (the history of individual development) during the present century. Almost all the attempts at classification made in the last century followed the path of the artificial system, which was first

established in a consistent manner by Charles Linnæus in 1735. The artificial system differs essentially from the natural one, in the fact that it does not make the whole organization and the internal structure (depending upon the blood-relationship) the basis of classification, but only employs individual, and for the most part external, characteristics, which readily strike the eye. Thus Linnæus distinguished his twenty-four classes of the vegetable kingdom principally by the number, formation, and combination of the stamens. In like manner he distinguished six classes in the animal kingdom principally by the nature of the heart and blood. These six classes were: (1) Mammals; (2) Birds; (3) Amphibious Animals; (4) Fishes; (5) Insects; and (6) Worms.

But these six animal classes of Linnæus are by no means of equal value, and it was an important advance when, at the end of the last century, Lamarck comprised the first four classes as vertebrate animals (Vertebrata), and put them in contrast with the remaining animals (the insects and worms of Linnæus), of which he made a second main division—the invertebrate animals (Invertebrata). In reality Lamarck thus agreed with Aristotle, the father of Natural History, who had distinguished these two main groups, and called the former *blood-bearing animals* (Enæma), the latter *bloodless animals* (Anæma). In the "System of the Animal Kingdom," which Lamarck published in 1801, he distinguished eleven classes; of these four were included among the *Vertebrata* (Mammals, Birds, Amphibia, and Fishes) and seven among the *Invertebrata* (Molluscs, Crustacea, Arachnida, Insects, Worms, Star-Fish, and Polyps). With the exception of the last two classes, which

contain lower animals of very different organization, the other classes of Lamarck were very natural main groups. Darwin's great predecessor was hence, at the time, the first zoologist essentially to improve and alter Linnæus' system, which had maintained its authority for sixty-six years.

The next important progress towards a natural system of the animal kingdom was made some decades later by two most illustrious zoologists, George Cuvier and Carl Ernst Bär. As has already been remarked, they established, almost simultaneously and independently of one another, the proposition that it was necessary to distinguish several completely distinct main groups in the animal kingdom, each of which possessed an entirely peculiar type or structure. In each of these main divisions there is a tree-shaped and branching gradation from most simple and imperfect forms to those which are exceedingly composite and highly developed. The *degree of development* within each type is quite independent of the peculiar *plan of structure*, which forms the basis of the type and gives it a special characteristic. The "type" is determined by the peculiar relations in position of the most important parts of the body, and the manner in which the organs are connected. The degree of development, however, is dependent upon the greater or less division of labour among organs, and on the differentiation of the plastids and organs. This extremely important and fruitful idea was established, in 1828, by Bär, who relied more distinctly and thoroughly upon the history of individual development, whereas Cuvier based his argument upon the results of comparative anatomy. But neither of them recognized the true cause of the remarkable relation-

ships pointed out by them, which is first revealed to us by the Theory of Descent. It shows us that the common *type* or plan of structure is determined by *inheritance*, and the degree of development or differentiation by *adaptation*.

Cuvier, as early as 1812, distinguished four different types in the animal kingdom, and divided it accordingly into four great main divisions (branches or circles). The first of these is formed by the vertebrate animals (Vertebrata), and comprises Linnæus' first four classes—mammals, birds, amphibious animals, and fishes. The second type is formed by the articulated animals (Articulata), containing Linnæus' insects, consequently the six-legged insects, and also the myriopods, spiders, and crustacea, but besides these, a large number of the articulated worms, or Annelida. The third main division comprises the molluscous animals (Mollusca)—slugs, snails, mussels, and some kindred groups. Finally, the fourth and last circle of the animal kingdom comprises the various radiated animals (Radiata), which at first sight differ from the three preceding types by their radiated, flower-like form of body. For while the bodies of molluscs, articulated animals, and vertebrated animals consist of two symmetrical lateral halves—of two counterparts or antimera, of which the one is the mirror of the other—the bodies of the so-called radiated animals are composed of more than two, generally of four, five, or six counterparts grouped round a common central axis, as in the case of a flower. However striking this difference may seem at first, it is, in reality, a very subordinate one, and the radial form has by no means the same importance in all "radiated animals."

The establishment of these natural main groups or types of the animal kingdom by Cuvier and Bär was the greatest advance in the classification of animals since the time of Linnæus. The three groups of vertebrated animals, articulated animals, and molluscs are so much in accordance with nature that they are retained, even at the present day, little altered in extent. But a more accurate knowledge soon showed the utterly unnatural character of the group of the radiated animals. Leuckart, in 1848, first pointed out that two perfectly distinct types were confounded under the name, namely, the *Star-fishes* (Echinoderma)—the sea-stars, lily encrinites, sea-urchins, and sea-cucumbers; and, on the other hand, the *Animal-plants*, or *Zoophytes* (Cœlenterata, or Zoophyta)—the sponges, corals, hood-jellies, and comb-jellies. Even at an earlier date, in 1845, Siebold, of Munich, had united the Infusoria with the Rhizopoda, under the name of Protozoa (primordial animals), into a special main division of the animal kingdom. By this the number of animal types was increased to six. It was finally increased to seven by the fact that modern zoologists separated the main division of the articulated animals into two groups: (*a*) those possessing *articulated feet* (Arthropoda), corresponding to Linnæus' Insects, namely, the Flies (with six legs), Myriopods, Spiders, and Crustacea; and (*b*) the footless *Worms* (Vermes), or those possessing non-articulated feet. These latter comprise only the real or genuine Worms (round worms, planarian worms, etc.), and therefore in no way correspond with the Worms of Linnæus, who had included the molluscs, the radiates, and many other lower animals under this name. Finally, the Tunicate Animals (Tunicata), which were formerly classed either with the

Molluscs or among the Worms, have latterly been recognized as an independent, eighth group of the animal kingdom.

Thus, according to the views of modern zoologists, which are given in all recent manuals and treatises on zoology, the animal kingdom is composed of eight completely distinct main divisions or types, each of which is distinguished by a characteristic plan of structure peculiar to it, and perfectly distinct from every one of the others. In the natural system of the animal kingdom—which I shall now proceed to explain as its probable pedigree—I shall on the whole agree with this usual division, but not without some modifications, which I consider very important in connection with genealogy, and which are rendered absolutely necessary in consequence of our view as to the history of the development of animals.

Even twenty years ago my investigations in the comparative history of development had led me to the conviction that the eight tribes of the animal kingdom were by no means equivalent main groups, but of entirely different significance both morphologically and phylogenetically. The eight tribes or types must not, therefore, as still often happens, be simply enumerated and described in a series one after the other, but must be again arranged into different subordinate groups, and their probable blood-relationship be critically taken into consideration. But this critico-phylogenetic examination must not take either comparative anatomy or comparative ontogeny exclusively as its standard; these two grand records of creation must be made use of in a comprehensive manner, and employed with morphological discretion for mutually supplementing each

other; and besides this, the third record of creation, palæontology, must likewise always be kept in view.

When examining the phylogenetic relationships of the eight tribes of animals upon these principles, and endeavouring to improve my first sketch of a phylogenetic classification (made in 1866 in my "General Morphology"), I came upon a new and essentially different idea of the Animal System. The fundamental principles of it I published in 1872, in my "Philosophy of the Calcareous Sponges" (in the fourth chapter of my "Monograph of the Calcispongiæ," vol. i. p. 465). This remarkable class of marine animals is characterized by such an extraordinary instability of bodily form, that, in fact, it is impossible to distinguish so-called "good species," *i.e.* "relatively constant species," in the usual sense of the word (compare above, vol. i. p. 305). During five years, and with extremely plentiful and complete material, I examined most thoroughly all the circumstances of their formation and development, and was thus enabled to trace back all the species of this class (of which either 111, or 289, or 591 may be distinguished according to wish) to one single common primary form, the *Olynthus*. With some justice, therefore, I may doubtless describe my "Monograph of the Calcareous Sponges" (the first attempt made to establish a phylogenetic system of a class rich in forms) also as an "Attempt at an Analytical Solution of the Problem of the Origin of Species."

That remarkable primary form of the Calcareous Sponges, *Olynthus* (Plate VI.), has since been proved to be the phylogenetic original form of all other Sponges, and is now universally considered as the common primary form of the whole class of Sponges. When, therefore, I compared

the Olynthus, as a simple sack composed of two layers of cells, with the similar two-layered germinal form of the Metazoa, the Gastrula (vol. i. p. 345), I came to the conviction that the former remained at a very low stage of development which is passed through in early youth by all other tissue-animals. This youthful form, the Gastrula, had till then been explained in many different ways, and been regarded as an entirely distinct germinal form in the divergent tribes of the animal kingdom. In opposition to this universally prevalent opinion, I endeavoured to show that the striking differences in the germinal forms are of subordinate importance, and only modifications of one and the same primæval form of the primary Gastrula. From this I inferred further, on biogenetical principles, a corresponding common primary form for all the many-celled animals, the Gastræa. The chapter in my "Philosophy of Calcareous Sponges" on the germ-layer theory and the pedigree of the animal kingdom, and which maintained, for the first time, the homology of the two primary germinal layers in all Metazoa, concludes with the following sentence: "Owing to this identity of the Gastrula in the representatives of the most different tribes of animals, from the Sponges up to the Vertebrates, I infer, on biogenetical principles, a common descent for animal phylæ from a single unknown primary form, which was essentially of the same form as the Gastrula: 'Gastræa'" (*l.c.* 1872, vol. i. p. 467).

In the "pedigree of the animal kingdom" which precedes the above sentence (p. 465), I derived the five higher animal tribes (Vertebrates, Molluscs, Tunicates, Arthropods, and Echinoderma) from the common group of the Cœlomati, from "Worms with a body-cavity." Of these I assumed

that they had originally proceeded from Acœlomi, or Platodes—"Worms without a body-cavity." For these latter, however, and for the Zoophytes, I believe I might assume a direct descent from the hypothetical Gastræa.

These outlines of the Gastræa theory, which were first communicated in my "Monograph of the Calcareous Sponges," I worked out further, during the following year, in my "Studies on the Morphology of the Infusoria" (Jena, Zeitsch., 1873, vol. vii. p. 560). Its proof in detail, as well as its application to the most important phylogenetic and morphological problems, are contained in my "Studies on the Gastræa Theory" (1873–1877). It received its first corroboration from the eminent English zoologist, Ray Lankester, who, in 1873, had independently come to similar conclusions. And it has further received most valuable support owing to the first comparative anatomist of our day, Carl Gegenbaur, having adopted it. Hertwig, Rabl, Selenka, Balfour, Rückert, Hatscheck, and many other embryologists have furnished further proofs in regard to it. And although attacked from various quarters, the Gastræa theory has proved itself correct in all essential points, and is nowadays recognized by most zoologists as a useful foundation for our modern phylogenetic system of the animal kingdom.

One of the most important consequences to the systematic arrangement was in the first place the complete separation of the single-celled Protozoa from the other many-celled animals, which I contrasted to the latter as Metazoa (see above, p. 59). Further, I distinguished among the Metazoa first two main groups. The two lower branches (Cœlenterata and Acœlomi) possess neither blood nor body-cavity;

these occur only in the five higher branches. Among the latter, however, the Cœlomati (or Worms with a body-cavity) represent the common primary group, from which the higher types of animal tribes have developed divergently.

With regard to the phylogenetic unity of the great groups of the animal kingdom, we may even now infer with sufficient certainty, from the numerous facts of comparative anatomy and ontogeny, that *all those animals which belong to one so-called "type" have a common origin.* For in spite of all the variety of external form developed within each of these types, the essential relative position of the parts of the body which determines the type is so constant, and agrees so completely in all the members of every type, that on account of their relations of form alone we are obliged in the natural system to unite them into a single main group. It, however, directly follows that this conjunction may have its expression in the pedigree of the animal kingdom. For the true cause of the intimate agreement in structure can only be the result of inheritance—that is, of actual blood-relationship. Hence we may, without further discussion, lay down the important proposition that all animals belonging to one and the same circle or type must be descended from one and the same original primary form. In other words, the idea of the circle or type—as employed in zoology since Cuvier and Bär's time to designate the few main groups or "sub-kingdoms" of the animal kingdom—coincides with the idea of "tribe" or phylum, as employed by the theory of descent for all those organisms which, most probably, are related by blood, and possess a common original root.

This important decision is met with at once by the question—in the form of a second phylogenetic problem—Where do these different animal tribes come from? Are they original primary forms of entirely independent origin, or are they also distantly related by blood among one another?

At first we might be inclined to answer this question in a *polyphyletic* sense, by saying that we must assume, for each of the great animal tribes, at least one independent primary form completely distinct from the others. On further considering this difficult problem, we arrive at the conclusion of a *monophyletic* origin of the animal kingdom, viz. that even the primary forms are connected at their lowest roots, and that they are derived from a single, common primæval form. And although we ignored the existence of the single-celled Protista, and merely examined the derivation of the many-celled Histons, nevertheless as regards *the animal as well as the vegetable kingdom, when closely and accurately considered, the monophyletic hypothesis of descent, based upon the Gastræa theory, will be found to be more satisfactory than the polyphyletic hypothesis.*

It is *comparative ontogeny* (embryology) which first and foremost leads to the assumption of the monophyletic origin of the whole animal kingdom. The zoologist who has thoughtfully compared the history of the individual development of various animals, and has understood the importance of the biogenetic principle (p. 361), cannot but be convinced that a common root must be assumed for the tribes of Metazoa, and that all animals, including man, are derived from a single, common primary form. The result of the

consideration of the facts of embryology, or ontogeny, is the following genealogical or phylogenetic hypothesis, which I have put forward and explained in detail in my "Studies on the Gastræa Theory" and in my "Anthropogeny."

The first and most important phenomenon we learn from comparative ontogeny, is the fact that every many-celled animal has developed out of a simple cell. This first cell is the Cytula, the progeny-cell or the so-called "first globule of the cleavage" (Fig. 19 *B*, p. 158). We have already examined its origin out of the fructified egg-cell, as well as the significance of the act of fructification (vol. i. p. 340). Corresponding to the ontogenetic cytula, we may regard the simple animal *cell,* or the *one-celled primary animal,* as the common phylogenetic primary form of the whole animal kingdom; in its simplest form it is met with still in a living state in the *Amœbæ* of the present day. Like these simple and still living Amœbæ, and like the naked egg-cells of many of the lower animals which cannot be distinguished from them (for instance, the egg-cells of the Sponges, Plate VI., Fig. 16), those very ancient primary Amœbæ were still perfectly marked cells; they probably moved about the primæval Laurentian ocean by means of changing processes, and took their nourishment and propagated by division in the same manner as the Amœba of to-day (see vol. i. p. 193). The existence of this *single-celled* Amœba-like *primary form* of the whole animal kingdom is proved by the extremely important fact that the fructified egg of all animals, of the sponge and the worm up to that of an ant and to that of man, is a simple cell. The ripe eggs of different animals frequently present very different shapes, accordingly as they may be enclosed by variously formed

coverings or burdened with nutritive yolk. But the youthful egg-cells are still naked and without any membrane, of the simplest construction, and at times they even creep about in the body like an Amœba—thus, for instance, in Sponges; they were formerly, in this case, even considered to be parasitical Amœbæ.

The hypothetical common single-celled primary form of the animal kingdom, whose former existence is proved by the *Cytula*, we may distinguish as *Cytœa*, or "Ancient original cell" (see p. 49). The question as to the original coming into existence of these *Cytœa* we have already answered, when we showed that the earliest primary forms of all single-celled creatures—hence also of the Cytæa—can only have been the simplest *Monera* (see p. 49, etc.).

It might, accordingly, be expected that in the ontogeny, the non-kernelled Monera-stage would precede the kernelled, single-celled stage. And, in fact, it was believed at one time that there existed, at the beginning of the individual development, a non-kernelled stage (Monerula); the Cytula was supposed to arise out of it merely by a kernel being newly formed. However, the recent important investigations on fertilization—already discussed in Chapter XIII.—have refuted this supposition. It would seem that the Monerula-stage has been lost by abridged inheritance (vol. i. p. 219).

From the single-celled stage, arose the simplest multicellular stage, namely, the cell-heap (Cœnobium), a small community of simple homogeneous cells. Even at the present day, in the ontogenetic development of every animal egg-cell, there first arises a globular heap of homogeneous naked cells, by the repeated self-division of the primary cell, the so-called "cleavage of the egg." We

called this accumulation of cells the *mulberry state* (Morula), because it resembles a mulberry or blackberry. This Morula-body occurs in the same simple form in all the different tribes of animals, and on account of this most important circumstance we may infer, according to the biogenetic principle, that *the most ancient, many-celled, primary form of the animal kingdom* resembled a Morula, and was, in fact, a simple heap of Amœba-like primæval cells, one similar to the other. We shall call this most ancient community of Amœbæ—this most simple accumulation of animal cells, which is recapitulated in the individual development by the Morula—the *Moræa* or *Synamœbium*. Among the different, still living Cœnobia of Protozoa, the simple cell-heaps of Lobosa and Flagellata may especially be considered to resemble them (compare Plate V., Fig. 3–5, and 13–15).

Out of this Synamœbium, in the early Laurentian period, there subsequently developed a third primary form of the animal kingdom, which had the shape of a hollow globule, and which therefore we shall name the *Blastæa*, or globular bladder. This Blastæa arose out of the Moræa by some fluid or gelatinous substance accumulating in the interior of the globular cell-heap. This caused all the homogeneous cells to push towards the surface, and thus, as a simple layer of cells, they formed a thin wall to the globular bladder beneath. The Amœboid processes of the cells began to move more rapidly and regularly, and became changed into permanent fringes of cilia. Owing to the ciliary movements of these fringes, the whole many-celled body was placed in a greater and more rapid state of motion, and its creeping motion became a swimming form

of locomotion. We can infer the occurrence of these most ancient phylogenetic processes from ascertained ontogenetic facts. For in precisely the same manner, even nowadays (in the ontogenesis of the lower animals of the most different tribes), Morula changes into a ciliated form of larva, sometimes called the *Blastula*, sometimes the "Blastosphæra," or bladder-germ (Fig. 19 *F*, *G*, p. 158). This Blastula is a bladder-shaped, globular body, which swims about in the water by means of its vibrating cilia. The thin wall bounding this globular bladder which is filled with fluid consists of a single layer of homogeneous, ciliated cells, the so-called germinal membrane (Blastoderm, Plate V., Fig. 6 *k*, 16 *k*). The globular hollow space, enclosed on every side equally by the germinal membrane, is termed the germ-cavity (Blastocœloma, *b*).

The great importance of the Blastula, as the most ancient primary form of the animal kingdom, was recognized with prophetic insight, as much as sixty years ago, by the able embryologist Bär. In his classic "History of the Development of Animals," he makes the bold remark that, "at their first appearance all animals are perhaps equal and merely hollow spheres;" and he explains this statement by the following remarks: "The further back we go in tracing the development, the more do we find an agreement even among very different animals. This leads us to the question, whether all animals, at the beginning of their development, are not essentially alike, and whether there does not exist a common primæval form for all. As the germ is the undeveloped animal itself, we may, and not unreasonably, maintain that the simple bladder-form (the Blastula) is the common primary form, out of which all animals have been

historically developed, and not only according to a mere idea of our own." This remarkable proposition, which was not absolutely or empirically established till half a century afterwards, appears to us nowadays all the more astonishing, as Bär at the time (1828) was very far from being in a position to prove his proposition worthy of credence. He himself had seen only a few germ-bladders; and the fundamental principles of the cell-theory were unknown till ten years afterwards!

Our hypothetical assumption that the Blastula germinal form of to-day represents the hereditary repetition of a primary form of Blastæa is rendered worthy of credence by the fact that perfectly similar forms still exist; for instance, various Volvocineæ and the already described Catallacta (Magosphæra, p. 86). The best known of these is the common "globular animalcule" (Volvox globator), a Cœnobium from the class of Flagellata, p. 85. The globular gelatinous body has on its surface a simple layer of whip-cells, the vibrating whips of which cause it to be driven about in the water as if swimming. In the mature Volvox globator a sexual division of labour is manifested, inasmuch as some of these cells change into egg-cells, others into sperm-cells. In the case of the Catallacta which resemble them, on the other hand, the globular heap of cells separates without there being any sort of sexual propagation. Every individual cell lives on independently (in the Amœba-form), grows by taking food, and encases itself. Within the globular case the single-celled organism propagates by repeated division (as in the case of egg-cleavage), and finally again forms a ciliated globule like the Blastula.

Out of the Blastula there then develops in all animal

tribes an exceedingly important and interesting animal form, which, in my "Monograph of the Calcareous Sponges," I have named, owing to its shape, the goblet-germ, or *Gastrula* (that is, larva with stomach or intestine) (Fig. 19 *I, K*, p. 158). This Gastrula outwardly resembles the Blastula, but is essentially different from it, by the fact that its inner cavity has an opening to the outside, and that its cellular wall does not consist of one layer of cells but of two layers. The Gastrula develops out of the Blastula by the wall of the latter showing a depression inwards (Fig. 19 *H*). The depressed half of the bladder finally comes in contact with the other side, and the original hollow space (the "germ-cavity") disappears. The important hollow space that is now formed by the depression is the *primary intestine* or "primary stomach" (Progaster or Archenteron), the first beginning of the alimentary canal; its opening is the *primary mouth* (Prostoma or Blastoporus). The two layers of cells forming the wall of the Progaster, and which at the same time form the wall of the body of the hollow Gastrula, are the two primary germ-layers, the outer skin (exoderm) and the inner skin (entoderm). This exceeding important larval form, the Gastrula, makes its appearance in the ontogenesis of animals of every tribe—in Sponges, Medusæ, Corals, Worms, Tunicates, Echinoderma, Molluscs, and even in the lowest Vertebrates (Amphioxus, see Plate XII., Fig. *B* 4; Ascidia, also Plate XII., Fig. *A* 4).

An interesting intermediate stage between the *Blastula* (Fig. 19 *F, G*) and the *Gastrula* (*I, K*) is formed by the semi-depressed stage of the former (Fig. 19 *H;* Plate V., Fig. 7 and 17). We may term it the *Depula,* or hood-germ. Now, as the origin of the Gastrula out of the Blastula

(by the invagination of the latter) has of late, after many investigations, been recognized as the original structural form of the Gastrula, we may assume that this ontogenetic stage corresponds with a definite ancestral form; and this stage of the germ also can be explained, according to our principle of development, by inheritance, as the inherited repetition of a corresponding phylogenetic stage; we will call the latter *Depœa* (Depos = goblet). At this intermediate stage there exist in the germ *two cavities*, one beside the other; the original germinal cavity (Blastocœl, *b*) degenerating, and the cavity of the primary intestine (Progaster, *a*) progressing. The latter is constantly increasing at the expense of the former; still in several of the Metazoa a portion of the germ-cavity remains, and may form a false body-cavity (Pseudocœl).

Owing to the ontogenetic occurrence of the Gastrula in the most different classes of animals from the Zoophytes up to the Vertebrates, we may, according to the biogenetic principle, safely draw the important conclusion that during the Laurentian period there existed a common primary form of the Metazoa, which, in all essential points, was formed like the Gastrula, and which we call the *Gastrœa*. This Gastræa possessed a perfectly simple, globular, or oval body, which enclosed a simple cavity of like form, namely, the progaster; at one of the poles of the longitudinal axis the progaster opened by a mouth, which served for the reception of nutrition. The body-wall (which was also the intestinal wall) consisted of two layers of cells or "germ-layers"—the *entoderm*, or intestinal layer, and the *exoderm*, or skin-layer. By the motion of the cilia or fringes of the latter, the Gastræa swam about freely in the Laurentian

ocean. Even in those higher animals, in the ontogenesis of which the original Gastrula-form has disappeared, according to the laws of abbreviated inheritance (vol. i. p. 219), the construction of the Gastræa-body has been transmitted to the phase of development which arises directly out of the Morula. This phase is a round disc which lies upon a globular "nutritive yelk," and consists of two cell-layers. The outer cell-layer, the *animal* or *neural layer* (Epiblast), corresponds with the exoderm of the Gastræa; out of it develops the outer, upper skin, the epidermis, with its glands and appendages, as well as the central nervous system. The inner cell-layer, the *vegetative* or *gastral layer* (Hypoblast), is originally the entoderm of the Gastræa; out of it develops the inner, nutrient membrane (epithelium) of the intestinal canal and its glands (compare my "Anthropogeny," Lecture XVI.).

Three different fundamental thoughts appear to give authority to our theory of the Gastræa: firstly, that the two primary germinal layers, in all Metazoa, are homologous or originally equal; secondly, that the hollow they enclose, the primary intestine, is phylogenetically the oldest organ of the Metazoa, as the primary organ of nutrition; and thirdly, that accordingly a primæval, long since extinct form of Gastræa must be regarded as the earliest common primary form of the Metazoa, and that in all essential points it resembled the simplest form of the Gastrula of to-day. This Gastræa-theory receives very strong corroboration from the fact that even nowadays there exists several low species of animals which in all essential points correspond with the hypothetical primary form of the Gastræa (Plate VI.). The best known and most interesting of these

animals is our common fresh-water polyp (Hydra). If we disregard certain trifling differences in the construction of the skin-layer, and also the simple wreath of tentacles which has arisen secondarily round the mouth, *the Hydra in all essential characteristics appears to be a permanent Gastræa;* it matures in this most simple state, and propagates by sperm-cells arising out of the skin-layer on the front part, and egg-cells on the back part. Another animal form, but little different from the primary form of the Gastræa, is the *Olynthus,* the above-mentioned primary form of the Sponges; a third and closely allied group is formed by the *Physemaria* (Prophysema), a fourth by the *Orthonectida* (Rhopalura). See Plate VI., and the following chapter.

By ontogeny we have thus gained for our hypothesis of the monophyletic origin of the animal kingdom five primordial stages: 1. The Amœba; 2. The Moræa; 3. The Blastæa; 4. The Depæa; and 5. The Gastræa. The former existence of these five earliest primary forms, which must have lived in the Laurentian period, follows as a consequence from the biogenetic principle, from the parallelism and the mechanico-causal connection between ontogenesis and phylogenesis (see vol. i. p. 356). The first four stages (the animal Amœbæ, Moræa, Depæa, and Blastæa), on account of their simple nature, might be reckoned among the Protista, or connected with the latter as actual primæval animals (Protozoa). But with the fifth stage, with the *Gastræa,* the actual animal kingdom begins, and with it a much higher state of organization. Its two germ-layers form the first tissue, the original foundation of all the organs of the Metazoa.

The phylogenetic development of the different animal

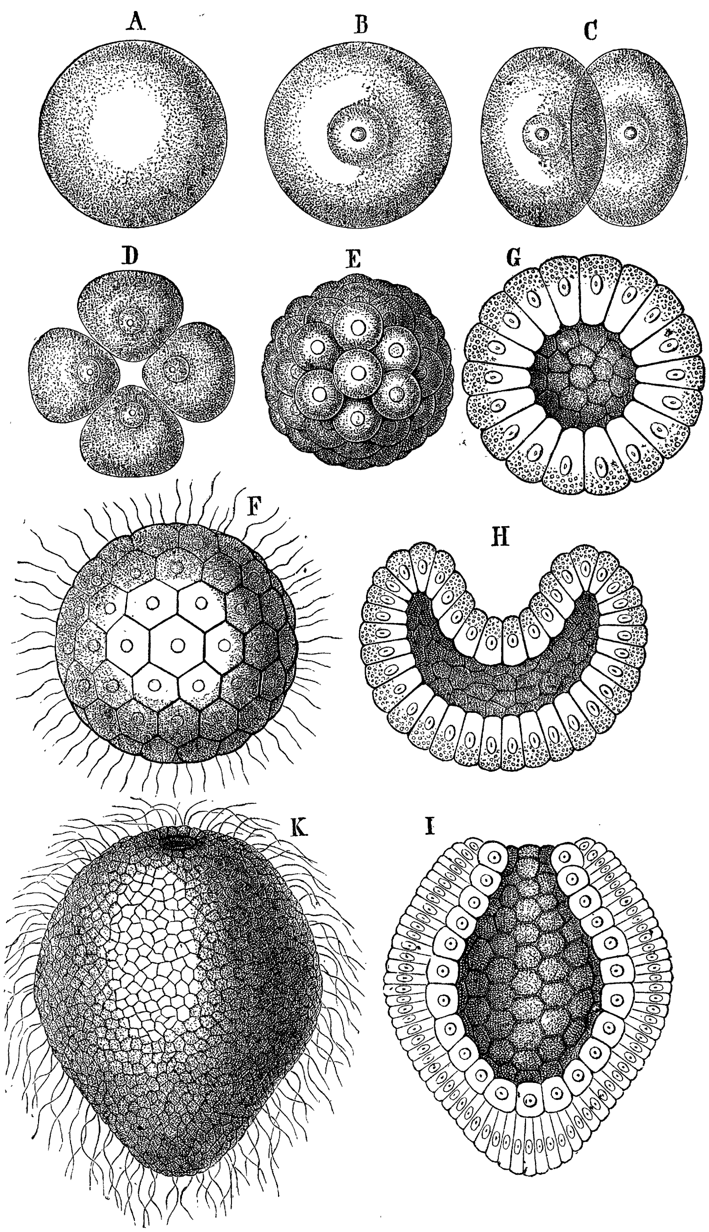


Fig. 19.—The development of a coral (Monoxenia Darwinii). *A.* Fructified egg-cell (kernel not visible). *B.* Progeny-cell (Cytula). *C, D.* Division of the Progeny-cell. *E.* Morula. *F, G.* Blastula. *H.* Depula. *I, K.* Gastrula. (Fig, *G, H*, and *I* given in cross-section.)

Form Value of the first five stages of the animal body, compared in the individual and the phyletic development.	**Ontogenesis.** The first five stages of the individual development.	**Phylogenesis.** The first five stages of the phyletic or historical development.
First Stage of Development. **A simple cell** (a kernelled plastid).	1. **Cytula.** Progeny-cell, or "first globule of the cleavage." Fig. 19 *B*.	1. **Cytæa.** Primordial cell (most ancient animal Amœba).
Second Stage of Development. **A solid community** (a dense aggregation) **of simple homogeneous cells.** (Cœnobium.)	2. **Morula.** (*Mulberry germ.*) Globular heap of homogeneous "cleavage spheres."	2. **Moræa.** (Synamœbium or community of amœbæ.) Most ancient cœnobia of homogeneous sociable cells (Amœbæ).
Third Stage of Development. A globular or oval **bladder** filled with fluid, the thin wall of which bladder consists of a single layer of homogeneous cells with cilia.	3. **Blastula.** (*Bladder-larva.*) Hollow bladder-shaped larva (or embryo), the simple wall of which consists of a single layer of cells. Fig. 19 *F*, *G*.	3. **Blastæa.** (*Whip-swimmers.*) Hollow bladder-shaped primæval animal, the thin wall of whose body consists of a single layer of cells with cilia.
Fourth Stage of Development. A hood-shaped body, with two separate layers of cells and **two cavities** (Blastocœl and Progaster).	4. **Depula.** (*Hooded larva.*) Hood-shaped larva with body-cavity (Blastocœl) and primary intestine (Progaster) ("Gastrula invaginata"). Fig. 19 *H*.	4. **Depæa.** Intermediate form between Blastæa and Gastræa, by the invagination of the former (Gastræa invaginata).
Fifth Stage of Development. A globular or oval-shaped **body with simple intestinal cavity and mouth-opening, composed of two layers;** on the outside the exoderm (dermal layer); inside, the entoderm (intestinal or gastral layer).	5. **Gastrula.** (*Goblet-larva.*) Many-celled larva with primary intestine and primary mouth; the intestinal wall with two layers (original common form of the animals with intestine). Fig. 19 *I*, *K*.	5. **Gastræa.** Many-celled organism with intestine and mouth; the intestinal wall with two layers (original primary form of all genuine animals: with intestine or Metazoa).

tribes from the common primary form of the Gastræa is in many respects very clear and simple, in other respects, however, very difficult and complicated. All zoologists whose opinions are worth consideration are now agreed that all the higher groups of animals are originally descended from lower groups. The lowest and oldest of all the Metazoa are the most simple Cœlenterata (*Hydra, Olynthus,* and *Gastræa*). It is also generally assumed that all the different organs of the higher animals have originally developed out of the two simple germinal layers of the Gastræa. But in what way the higher tribes originated out of the lowest Metazoa, how the general blood-relationships between them are to be conceived, and more especially, how the first origin of the several organs out of the germinal layers is to be explained—these are questions in regard to which opinions still differ very widely. In my "Monograph of the Calcareous Sponges," and more fully in my "Studies on the Gastræa Theory," I had pointed out that the most important difference in the organization of the lower and higher animals was that the latter had developed a body-cavity (Cœloma) and a blood-system, whereas these were wanting in the former. In accordance with this I classed the zoophytes (Cœlenterata) and the worms without body-cavity (Accœlomi) as Lower animals. To these "*bloodless animals*" (Anæmaria) I opposed all the higher animal tribes as "blood-bearing animals" (Hæmataria), all of which possess a body-cavity, and most of them a system of blood-vessels. As a primary group of these Hæmataria (originally derived from Accœlomi), I regarded the "Worms with body-cavity" (Cœlomati), and from these I derived, as diverging branches, the four higher types, the

tribes of Molluscs, Echinoderma, Articulated Animals, and Vertebrates (see my "Calcareous Sponges," vol. i. p. 465; and my "Gastræa Theory," Part I. pp. 54, 55).

The important question of the origin and the systematic significance of the body-cavity has since then been very fully discussed in a great number of treatises, most fully and most clearly by the brothers Hertwig, in their "Studies on the Germinal Layers." The fourth part of these Studies is entitled, "The Cœlom Theory: an attempt to explain the middle germinal layer" (Jena, 1881). They there distinguish three main groups of Metazoa: I. The Cœlenterata (Animal-plants or zoophytes) without any body-cavity, only an intestinal cavity; II. The Pseudocœlia, with a pseudocœl, or "false body-cavity," due to the formation of a fissure in the middle germinal layer, between the inner and outer germinal layer (Molluscs and Plathelminthes, Wheel-animalcules and Moss-polyps); III. The Enterocœlia, with "true body-cavity" (Enterocœl), formed out of a couple of pouches which develop from the sides of the primary intestine, and become pinched off from it, as in the case of most Worms (Cœlminthes), the Echinoderma, Articulata, and Vertebrata.

The "Cœlom Theory" of the brothers Hertwig contains numerous excellent discussions on the relationships between the great animal tribes, and seemed for a time to give a very simple explanation of many of the puzzling questions connected with these. However of late the chief propositions of their theory, more especially the distinction they make between the pseudocœl and the enterocœl, and their systematic application of these differences, have been sharply attacked from various quarters, and, it seems,

cannot altogether be upheld. Hence I prefer here, in the first place, to distinguish only those two main groups of Metazoa which I had already contrasted as the Anæmaria and Hæmataria; as a more suitable designation I now choose for the former the name of *Cœlenteria* (*Lower animals*); for the latter, *Cœlomaria* (*Higher animals*).

The Cœlenteria, or Lower animals (or the Cœlenterata in the widest sense), are looked upon by most zoologists as a single tribe. Without in any way doubting the unity of the tribe, I consider it more correct, and certainly more advantageous for the phylogenetic classification, to divide this class into four distinct phyla, of very different organization. The lowest and earliest of these groups, the root of the whole Metazoa kingdom, is formed by the primary group of the *Gastræades*, or primary animals; in the main permanent forms of Gastræa. Out of these, probably, were developed as three divergent classes: (1) the Sponge-animals (*Spongiæ*); (2) the Sea-nettles (*Cnidaria*); and (3) the Flat-animals (*Platodes*).

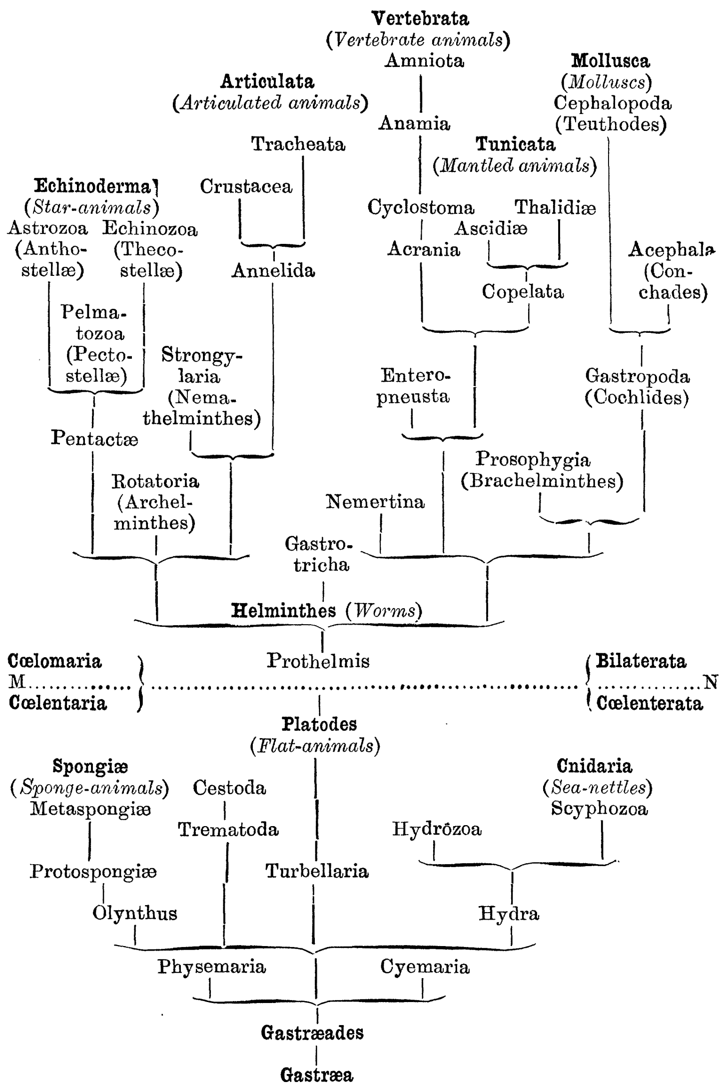
The group of the Platodes probably gave rise to the second main division of the Metazoa, the large group of the Cœlomaria, or Higher animals (Bilaterata). Of these the lowest group, the class of Worms (Helminthes), is directly connected with the Platodes. From the main group of the Helminthes there probably arose four distinct tribes independent of one another—the Molluscs, the Echinoderms, the Articulata, and the Chordonia; the latter separated early into two very divergent groups, the Tunicates and the Vertebrates.

The most important differences in the typical organization of these ten tribes of Metazoa are given briefly in the

tabular survey on p. 164. The hypothetical pedigree drawn up on the opposite page shows how their phylogenetic connection may approximately be conceived of in the present imperfect state of our knowledge on the subject. But in regard to it, as well as regards all the following pedigrees, I must expressly again remark that, owing to the nature of the case, their value can only be provisional. But those naturalists who examine the history and pedigrees of organisms more deeply, will soon become convinced that these pedigrees are of great value as tentative hypotheses, and that they are indispensable for a clear solution of the complicated phylogenetic problems.

SURVEY OF THE TEN TRIBES OF THE METAZOA,
Giving their Characteristic Peculiarities.

Tribes (*Phyla*).		*Articulation, Fundamental Form.*	*Typical Nerve-centre.*	*Special Peculiarities.*
I. Cœlentaria (Cœlenterata, Zoophyta, Anæmaria). Metazoa without body-cavity, without blood, without anal opening.				
1. **Gastræades**	Primary animals	No articulation, fundamental form of one axis	No nerve system	Body consists merely of two germinal layers
2. **Spongiæ**	Sponge-animals	No articulation, form quite irregular	No nerve system	Microscopic skin-pores for the reception of food
3. **Cnidaria**	Sea-nettles	No articulation, form radiated	Nerve system sometimes wanting, sometimes ring-shaped	Microscopic nettle-organs in the outer skin
4. **Platodes**	Flat-animals	No articulation, form bilateral	Simple cerebral knot and two longitudinal threads	A pair of nephridia, or primary renal tubes
I. Cœlomaria (Bilaterata, Bilateria, Hæmataria). Metazoa with body-cavity, mostly with blood and with anal opening.				
5. **Helminthes**	Worms	No articulation, form bilateral	Simple cerebral knot or gullet-ring	Want of the positive characteristics of the other Cœlomaria
6. **Molluscs**		No articulation, form bilateral	Double gullet-ring with three pairs of knots	Dorsal mantle with calcareous case. Ventral muscular foot
7. **Echinoderma**	Star-animals	Outward articulation, form five-rayed	Ventral five-rayed nervous system	Ambulacral system. Calcified leathery skin
8. **Articulata**	Articulated animals	Outward articulation, form bilateral	Segmented ventral nerve-cord with gullet-ring	Cuticular chitinous skeleton of the skin
9. **Tunicata**	Mantled animals	No articulation, form bilateral	Brain-knot (degenerated dorsal nerve-cord)	Cellular mantle of tissue. Branchial gut. Endostyle
10. **Vertebrata**	Vertebrate animals	Inward articulation, form bilateral	Developed spinal nerve-cord (and in most cases brain)	Chord or vertebral column. Branchial gut. Ventral heart



M.........N boundary between the Bilaterata and the Cœlenterata.

CHAPTER XXI.

PEDIGREE AND HISTORY OF CŒLENTERIA AND WORMS.

Phylogeny of the Cœlenteria, or Cœlenterata: Gastræades (Gastræmones, Cyemaria, and Physemaria).—Spongiæ.—Their Organization.—Homology between the "Ciliated Chambers" and the Gastræa.—Skeletal Formations of the Sponges.—The Three Classes of the Sponge Tribe: "Cementing Sponges" (Malthospongiæ), Silicious Sponges (Silicispongiæ), Calcareous Sponges (Calcispongiæ).—Their Common Primary Form: Olynthus.—Ammoconidæ.—Tribe of the Sea-nettles (Cnidaria, or Acalephæ).—Their Organization.—Derivation of all Cnidaria from most Simple Polyps (Hydra).—Hydropolyps and Scyphopolyps.—Polyphyletic Origin of the Medusæ and Siphonophora.—Ctenophora.—Corals.—Tribe of the Flat-animals (Platodes): the Three Classes of Gliding-worms (Turbellaria), Sucker-worms (Trematoda), and Tape-worms (Cestoda).—Radial and Bilateral Fundamental Form.—Nephridia.—Phylogeny of the Cœlomaria, or Bilaterata: Metazoa with Body-cavity, Blood, and Anus.—Derivation of the Five Higher Classes of Animals from Worms (Helminthes).—The Four Main Classes and Ten Classes of Helminthes.

In now undertaking the difficult task of giving the outlines of a general pedigree and history of the animal kingdom, we first of all base our attempt on the distinctive characters of the ten great tribes, or phyla, of the Metazoa (see p. 162). By examining and comparing the differences in the development and in the structure of their bodies from the most general aspects, we were enabled, in the first place, to divide them into two main groups—the Lower Animals, or

PLATE XVIII.

NERVOUS SYSTEMS OF VARIOUS ANIMALS.

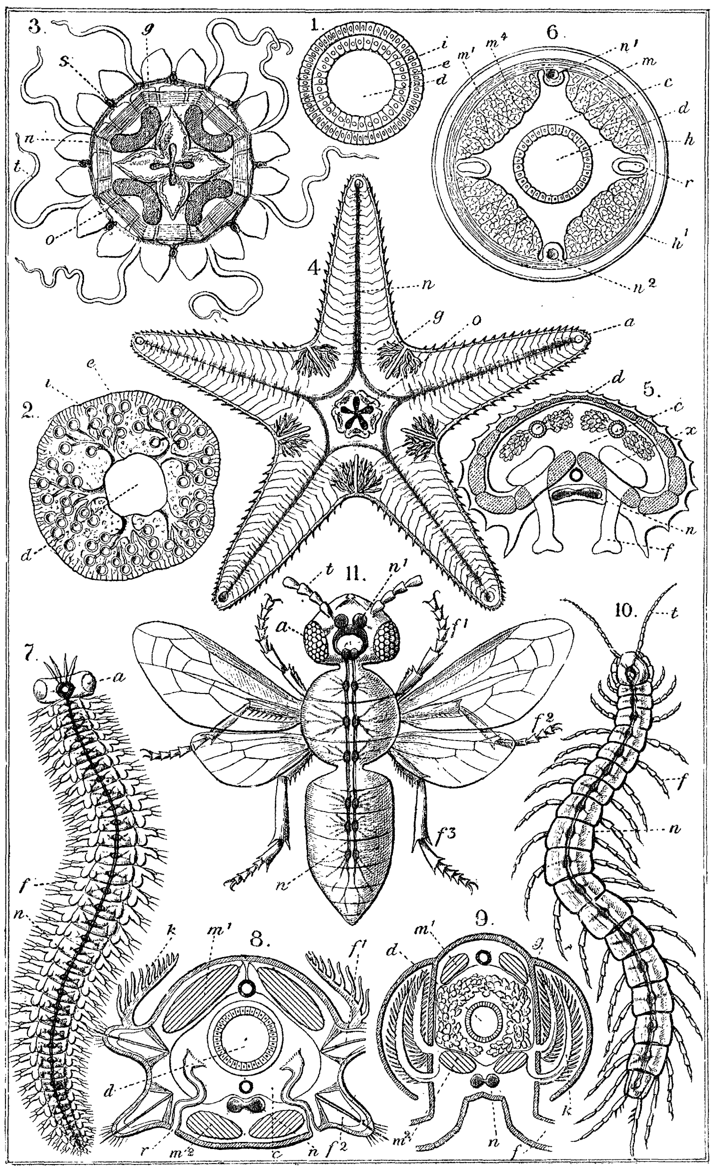
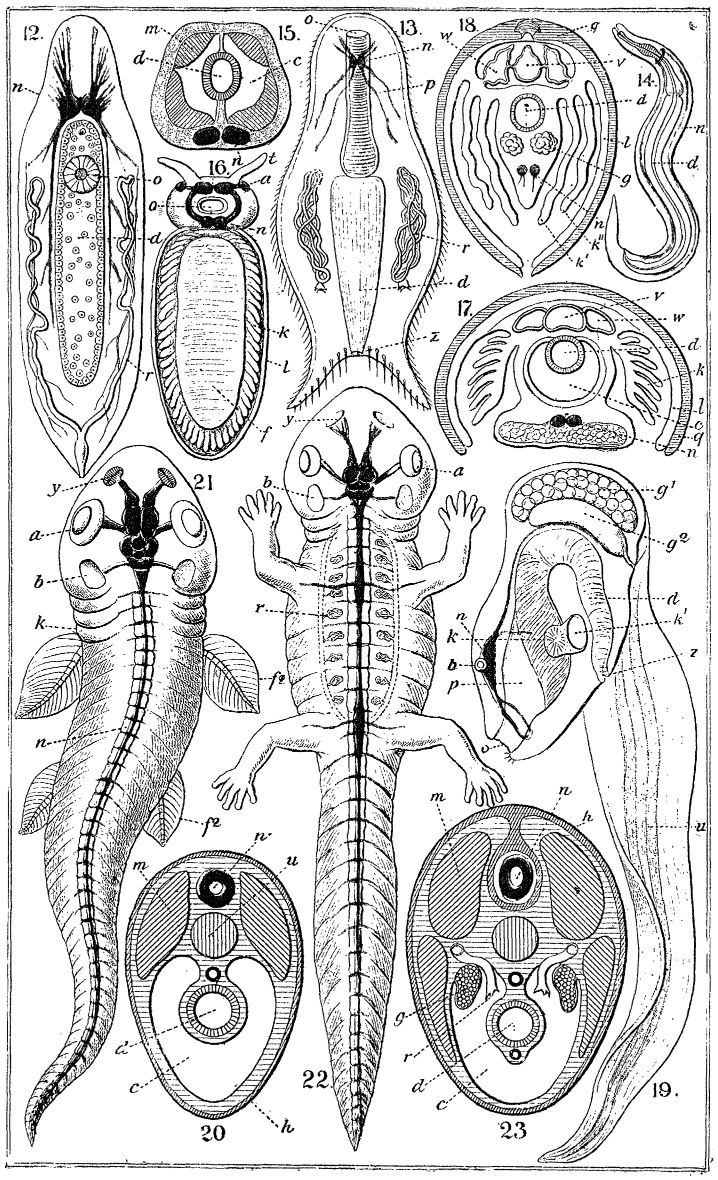


PLATE XIX.

Nervous Systems of Various Animals.



Cœlenteria, and the Higher Animals, or Cœlomaria. The Cœlenteria (or "Cœlenterata" in the widest sense) possess neither body-cavity nor blood; their intestine possesses only a single orifice, the mouth, but no anus. On the other hand, the Cœlomaria (or "Bilaterata") possess a body-cavity apart from the intestine, and, usually, also blood and blood-vessels; in most cases, also, the intestine has two outward orifices, mouth and anus; however, it not infrequently happens that the anus has disappeared through degeneration. There can be no doubt that, of these two main groups of Metazoa, the more simply constructed Cœlenteria are the earlier and original group. Only at a later period can the Cœlomaria have developed out of them, and moreover, in the first place, by the formation of a body-cavity (Cœloma), and subsequently by the development of an anus and a system of blood-vessels.

The main group of *Cœlenteria*, or Cœlenterata (formerly often termed Animal-plants, or Zoophytes), is composed of four different large groups, or phyla; these four groups are: (1) the Primary-intestine animals (Gastræades); (2) the Sponges (Spongiæ); (3) the Sea-nettles (Cnidaria); and (4) the Flat-animals (Platodes). The last three main classes probably developed, independently of one another, out of the first group, the Gastræades.

The first main group of the Cœlenteria, the class of Primary-intestine animals (*Gastræades*) must, for reasons already given, be regarded as the *common, original primary group* of all Metazoa. For in the case of all genuine animals, or Metazoa, the individual development of the body begins with the formation of a true *Gastrula.* From this exceedingly important fact we are obliged to infer, accord-

ing to the biogenetic principle, that the common, primæval, long since extinct primary form of the animal kingdom, the *Gastræa*, was essentially of the same construction as this Gastrula: a simple oval or goblet-shaped body of one axis, its stomach-cavity opening outwardly by a mouth, and its wall consisting of two layers of cells, the two primary germinal layers (see Fig. 19 *I, K*, p. 158). These two simple layers of cells, at the same time, formed the first actual tissue of the animal body, one-layered coverings, or *epithelia*. All other tissues of the more highly developed animal body—sinews, muscles, and nerves—must be regarded as "secondary tissue," inasmuch as they were developed only subsequently out of the primary epithelia. Several of these cells were even employed by the Gastræades for propagation, and developed either into the female egg-cells or into the male sperm-cells.

It is very probable that the earliest primary group of the Metazoa was represented in the Laurentian primæval ocean by many different Gastræades, and that they swam about freely by means of their garb of vibratile fringes, like ciliated Infusoria or Ciliata. As in the case of many of these Infusoria (more especially the Tintinnoids), their delicate, gastrula-like body was probably protected by the formation of a case enclosing it. It is even possible that many of the minute, roundish, oval or oblong shells, which are met with even in the earliest Neptunic formations, and which are sometimes ascribed to the Pteropods, sometimes to other animalcules, originally belonged to the Gastræades. We shall meanwhile designate this earliest hypothetical primary group of Metazoa as *Gastræmones*.

In addition to these hypothetical Gastræmones, however,

the group of Gastræades contains two other small and still living classes of the simplest Metazoa, the Cyemaria and Physemaria. The class of *Cyemaria* consists of minute swimming marine animals, which lead a parasitical life in the body-cavity of the Echinoderma and in the renal cavity of the Molluscs. They may be regarded as the simplest Metazoa which have retained the original organization of the Gastræa; this is especially the case with the remarkable *Orthonectidæ* (Rhopalura). Their oval or spindle-shaped body (Plate VI., Fig. 9, 10) has but one axis (with a circular transverse section), and consists of two layers of cells. The cilia of the outer layer of cells (of the exoderm, or animal germinal layer) aid it in swimming; the cells of the inner mass (of the entoderm, or vegative germinal layer) form egg and sperm cells, and indeed both kinds of sexual cells originate in differently formed individuals (gonochoristic persons). In the closely related *Dicyemidæ* (Dicyema), the entoderm is represented by a single large central cell, as is temporarily met with in many forms of Gastrula.

A second still existing class of the Gastræades is formed by the curious *Physemaria* (Prophysema and Gastrophysema, Plate VI., Fig. 6–8). I have given a minute account of these Physemaria (which are often confounded with similar Rhizopods, Haliphysema) in my "Studies on the Gastræa Theory" (III. The Physemaria, Gastræades of the Present Day, Plates IX.–XIV., 1876). They are simple goblet-shaped pouches of one to three millimetres in length, and adhere to the bottom of the sea. A short spiral wreath of cilia at its mouth-opening sends the food into its simple stomach-cavity, the walls of which consist of two layers of

cells, the two primary germ-layers. The outer germinal layer, or exoderm, forms a skeleton of grains of sand and other foreign bodies; the inner germinal layer is a ciliated epithelium, used for obtaining nourishment; some of these latter cells change into egg-cells, others into sperm-cells. Out of the fructified egg arises a Gastrula, which swims about for a time, and then becomes adherent, and again grows into a Physemarium.

Very closely allied to these Physemaria are the simplest forms of true *Sponges* or Sponge-animals (*Spongiæ* or *Porifera*). The only essential feature in these is that the stomach-wall shows numerous fine dermal holes or pores. Through these dermal holes the nourishing stream of water enters the stomach-cavity, and is driven out at the mouth-cavity (osculum). All Sponges live in the sea, with the single exception of the fresh-water Sponge (Spongilla). For long these animals were regarded as plants, and subsequently as Protista; in many manuals they are even now classed among the Protozoa. But since I demonstrated their development out of the Gastrula, and the structure of their body to consist of two germinal layers (as in all other higher animals), their close relationship with the Physemaria and the Cnidaria seems, at last, to be a settled point. It is more especially the Olynthus (which I regard as the common primary form of the Sponges) that has thrown a complete and unmistakable light on this point (Plate VI., Fig. 1–5). It is from a simple thin-walled sack, like the *Olynthus*, that the different forms of Sponges are developed by a thickening of the stomach-wall and the development of a vascular system in it. The characteristic germinal form of the *Olynthula*, which first arises out of

the Gastrula of the Spongiæ, repeats even nowadays the hereditary image of this hypothetical primæval Sponge (Archolynthus). It resembles a *Prophysema*, whose thin goblet-shaped wall is perforated by numerous fine pores.

The group of Sponges, which is rich in species, is distinguished above all other classes of animals by the perfect irregularity of the outward form of their bodies, and by the original simplicity of their internal structure and their formation of tissue. Almost all Sponges adhere to the bottom of the sea, in the form of irregular clumps and knolls, thin crusts, branching bushes, etc. Rarely is their shape regularly cylindrical, cup-shaped, or even fungiform. The size of the smaller species amounts only to a few centimetres, whereas the largest sometimes attain a size of more than a metre in diameter. Some are quite soft, gelatinous, or crumbly; others tolerably firm, or like indiarubber; and others, again, knotty, or even hard as stone.

The section of a Sponge-body invariably shows a more or less complicated vascular system filled with water. It opens on the surface by countless fine cutaneous pores, whereas the larger tubes of the interior either open into one central cavity or into several larger cavities. All of these, as a rule, open outwardly by a principal orifice (osculum). The stream of water which introduces the food (microscopic particles of plants and dead animal bodies, Protista and such things) into the body, and is sucked up through the fine pores, is again emitted by these same openings. Generally, along the course of the vessels there are arranged countless ciliated chambers of a roundish shape; the vibrating movements of the ciliated cells, which live there,

keep the stream of water in motion. *Every ciliated chamber must be conceived of as a most simple sponge-individual equal in value to a Gastrula.* The whole Sponge, therefore, may be regarded as a *Gastræa-Cormus*, as a community composed of numerous small Gastræa-persons, similar to a stock of Hydropolyps. This explanation would also account for the striking irregularity of the outward form which is met with in most animal-stocks.

Organs of sense, nerves, and muscles are wanting in the Spongiæ, and, in fact, the vital activity of these lowest Metazoa remains at a very low stage. Sensation and motion (contraction under irritation) is scarcely observable in most of them. Propagation is effected by amœbæ-like egg-cells and fructifying sperm-cells, which develop within the dense body-mass. This latter is composed of tissues of different sorts, and generally of parts of the skeleton lodged in the body-mass. These tissues and the two different kinds of sexual cells arise out of the exorderm, or the outer germinal layer of the Gastrula, whereas the inner germinal layer, the entoderm, furnishes the ciliated cells. The skeleton-parts, which determine the varying density of the Sponge, present a great variety, both in form and substance. The Sponges may, accordingly, be divided into three classes —Cementing Sponges (*Malthospongiæ*), Silicious Sponges (*Silicispongiæ*), and Calcareous Sponges (*Calcispongiæ*).

The first class, the "Cementing Sponges" (Malthospongiæ), do not form any mineral skeleton; they neither produce flinty nor calcareous spicules. The first order of these, the *Mucous Sponges* (*Myxospongiæ*), in fact, possess no skeleton or any firm framework whatever (Halisarca, Chrondrosia). In the second order, the *Sand Sponges* (*Psammospongiæ*),

the absence of a skeleton is made good by masses of sand and other foreign bodies gathered from the bottom of the sea (as in the case of the remarkable "deep-sea" Keratosa —Ammoconidæ, Psamminidæ, and Stannomidæ—discovered by the *Challenger*, and recently described by me). The third order of the Malthospongiæ is formed by the large and important group of *Horny Sponges* (*Ceraspongiæ*), whose soft body is supported by a firm fibrous skeleton. This fibrous skeleton consists of a framework of so-called "horny fibres," a very elastic organic substance not readily destroyed. This is the case, for instance, in our common *Bath Sponge* (Euspongia officinalis), the purified skeleton of which we use daily when washing. The living Bath Sponge forms fleshy, black-brown clumps, the inner fibrous skeleton of which is perceptible only when cut through. In other horny sponges, during the formation of the horny fibres, grains of sand and other foreign bodies become lodged in them, in others flinty spicules.

These latter are directly allied to the true *Flinty Sponges* (*Silicispongiæ*). Here the skeleton consists wholly or for the most part of flinty spicules, sometimes with, sometimes without, the horny substance. To these belongs the large group of the Halichrondriæ as well as the fresh-water Sponge (*Spongilla*). A special division of these is formed by the beautiful Glass Sponges (*Hyalospongiæ* or *Hexactinellæ*). Their skeleton consists of six-rayed flinty spicules, frequently woven into an extremely pretty trellis-work; thus, more especially, in the celebrated Venus' Flower Basket (Euplectella). The Anchor Sponges (Phlœospongiæ) are distinguished by three or four-rayed silicious spicula. The systematic classification of these, as well as the above-

mentioned Silicious Sponges, is of especial interest to the Theory of Descent, as was first pointed out by Oscar Schmidt, one of the first authorities on this group of animals. In no other group, perhaps, can the unlimited plasticity of the specific form and its relation to Adaptation and Inheritance be so clearly followed step by step; in scarcely any other group is the species so difficult to limit and define.

This proposition, which applies to the great class of the Silicious Sponges, applies in a still higher degree to the smaller but exceedingly interesting class of the Calcareous Sponges (*Calcispongiæ*). The sixty plates of figures which accompany my Monograph of the class, explain the extreme plasticity of these small sponges, "good species" of which, in fact, cannot be spoken of in the usual systematic sense. We find among them only varying series of forms, which do not even completely transmit their specific form to their nearest descendants, but by adaptation to subordinate, external conditions of existence perpetually change. It frequently occurs here, that there arise out of one and the same stock different form-species, which, according to the usual system, would belong to several quite distinct genera; this is the case, for instance, with the remarkable Ascometra. The entire external bodily form is much more pliable and protean in Calcareous Sponges than in the Silicious Sponges; they are characterized by possessing calcareous spicules, forming a beautiful skeleton. Through the study of the comparative anatomy and ontogeny of calcareous sponges, we can recognize, with the greatest certainty, the primary form of the whole group, the sack-shaped *Calcolynthus* (Plate VI., Fig. 3–5). This is a simple Olynthus, the

thin, porous wall of whose body is supported by calcareous spicules. Out of this *Calcolynthus,* which is still very closely allied to the *Gastræa,* there arose in the first place the order of *Asconidæ;* the two other orders of the Calcareous Sponges, the *Leuconidæ* and *Syconidæ,* developed out of them subsequently as diverging branches. Within these orders, the descent of the individual forms can again be traced step by step. Thus the Calcareous Sponges in every respect confirm the proposition which I have elsewhere maintained, that "the natural history of Sponges form a connected and striking argument in favour of Darwin."

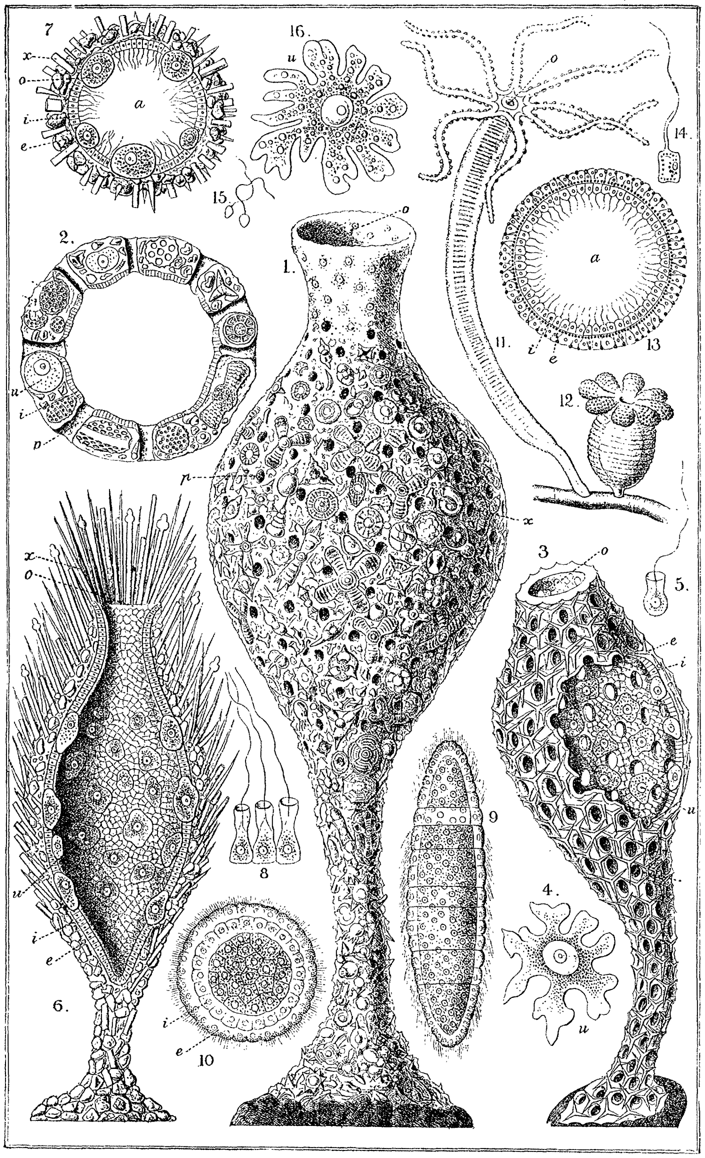
Quite recently I was fortunate enough to discover among the already mentioned deep-sea Psammospongiæ, or Sand Sponges, a few insignificant little forms, which are still very closely allied to the common primary form of the Spongiæ, the *Olynthus.* These are the Ammoconidæ, which were raised up from a depth of between two and three thousand metres in the tropical ocean by the *Challenger* Expedition. The simplest form among these Ammoconidæ is the remarkable Ammolynthus (Plate VI., Fig. 1, 2). Its oval or urn-shaped body is a simple thin-walled, porous sack. It resembles the Calcolynthus (Fig. 3), a drawing of which I first gave in my "Monograph on the Calcareous Sponges" in 1872. However, the delicate calcareous spicules which support the exoderm, or outer layer, of the Calcolynthus, are in the Ammolynthus substituted by the pretty silicious cases of various kinds of Radiolaria, which the small sponge has taken into itself from the Radiolaria-slime of the bottom of the ocean (Fig. 1, 2 *x*). Another species of Ammolynthus forms its skeleton of the calcareous shells of the Globigerina-

slime. In between these strange constituent parts of the skeleton are scattered, in the exoderm, the amœbæ-like egg-cells and the ciliated cells of the male seed. The intestinal layer, or entoderm, of the Ammolynthus, is formed (as in the case of the Calcolynthus) by a simple layer of flagellate cells, which line the primary intestinal cavity. Both sponges thus, in the simple construction of their body, are still very closely allied to the Gastræa.

Some other Ammoconidæ, which were discovered by the *Challenger* in other parts of the bottom of the deep-sea (partly in the Pacific, partly in the Atlantic Oceans), differ from the very simple *Ammolynthus* by possessing a branched shape. *Ammosolenia* forms delicate bushes (like *Leucosolenia*) with cylindrical branches, all of which possess a terminal mouth-opening. In the *Ammoconia* the branches grow together and form a loose network (as in the case of *Auloplegma*). Every branch of this branching body possesses the value of a Gastræa (like the hydranths of a Hydropolyp-stock). These different forms of Ammoconidæ correspond exactly with the characteristic main forms of the Asconidæ among the Calcareous Sponges. In both orders the usual roundish ciliated chambers of the Sponges are replaced by cylindrical tubes. This difference of structure is very important, and can be compared only with the structural difference of the tubulous and acinous glands. Perhaps, accordingly, it would be more correct to divide the whole tribe of Sponges into two classes; the first class would be formed by the *Tube Sponges* (*Protospongiæ*), with tube-shaped or tubular gastral individuals (Ammoconidæ and Asconidæ); the second class would comprise all other sponges, the *Chambered Sponges* (*Metaspongiæ*), with

PLATE VI.

GASTRÆADÆ.



1, 2. AMMOLYNTHUS; 3—5. CALCOLYNTHUS; 6—8. PROPHYSEMA; 9 10 RHOPALURA; 11—16. HYDRA.

bladder-shaped or acinous gastral individuals, the so-called "ciliated chambers." This class might again be divided into Malthospongiæ (without self-formed mineral spicules), Silicispongiæ (with flinty spicules), and Calcispongiæ (with calcareous spicules). Phylogenetically, the Metaspongiæ would be derived from the Protospongiæ, as the Olynthus belongs to the latter.

A much higher stage of organization than is manifested by the Sponges is attained by the great tribe of the *Sea-nettles* (*Cnidariæ* or *Acalephæ*). The numerous beautiful forms of swimming *Medusæ* and *Siphonophora,* adherent *Corals* and *Polyps,* which form the true floral world of the ocean, reveal to us a series of the most interesting stages of development of the animal body. And yet the lowest forms of this many-branched tribe (*Hydra,* Plate VI., Fig. 11–16) still stand very nearly allied to the Olynthus and the Gastræa, and hence to the root of the whole kingdom of the Metazoa. The long since extinct *Archydra* must be looked upon as the common primary form of the whole group; it was a small marine "primæval polyp," which has left a closely related and but little changed descendant in the still living and common fresh-water polyp (*Hydra*). The Archydra was probably very closely allied to the Physemaria (Fig. 6, 7), and to the simplest forms of Spongiæ (Fig. 1–5), but differed essentially from them in possessing tentacles or nettle-organs, and in the absence of cutaneous pores. Out of the Archydra there first developed the different Hydroid polyps, some of which became the primary forms of Corals, others the primary forms of the Medusæ. The Siphonophora, and perhaps also the Ctenophora, developed later out of a branch of the latter.

The Sea-nettles differ from the Spongiæ (with which they essentially agree in the characteristic formation of the system of the alimentary canal) on the one hand by the absence of cutaneous pores, and on the other by the formation of a wreath of tentacles and the permanent possession of nettle-organs. These are small bladders filled with poison, large numbers—generally millions—of which are scattered over the skin of the Sea-nettles. These serve as weapons of defence or attack, for when touched they emerge out of the skin and empty their poisonous contents.

The small *Polyps* (*Hydrusæ*) must be regarded as the oldest and lowest of the five classes of Sea-nettles. They differ from a *Physemarium* or adherent Gastræa only by their nettle-organs and by a wreath of feelers or tentacles surrounding the mouth. A few live isolated as single persons; the majority, by budding, form stocks which are composed of numerous persons. These are found everywhere adhering to the bottom of the sea and resemble pretty little trees. The lowest and simplest members of this class are the small *Fresh-water Polyps* (*Hydra* and *Cordylophora*). We may regard them as the but little changed descendants of those primæval Primary Polyps (Archydræ), which during the Primordial period gave rise to the whole division of Sea-nettles. The curious fresh-water Polyp (*Hydra*, Plate VI., Fig. 11–16), which is found everywhere in our ponds, is one of the most interesting of the lower animals on account of its simple, typical structure, and on account of its great capacity for dividing.

The second class of Sea-nettles is formed by the beautiful *Hood Jelly-fish*, or *Medusæ* (Plate VI., Fig. 8–12). They are found in all seas, and are often seen swimming about in

immense numbers on the surface of the water. Hood jelly-fish are mostly of the form of a bell, a mushroom, or an umbrella, from the rim of which hang numerous long, delicate tentacles. They are among the most beautiful and most interesting inhabitants of the sea.

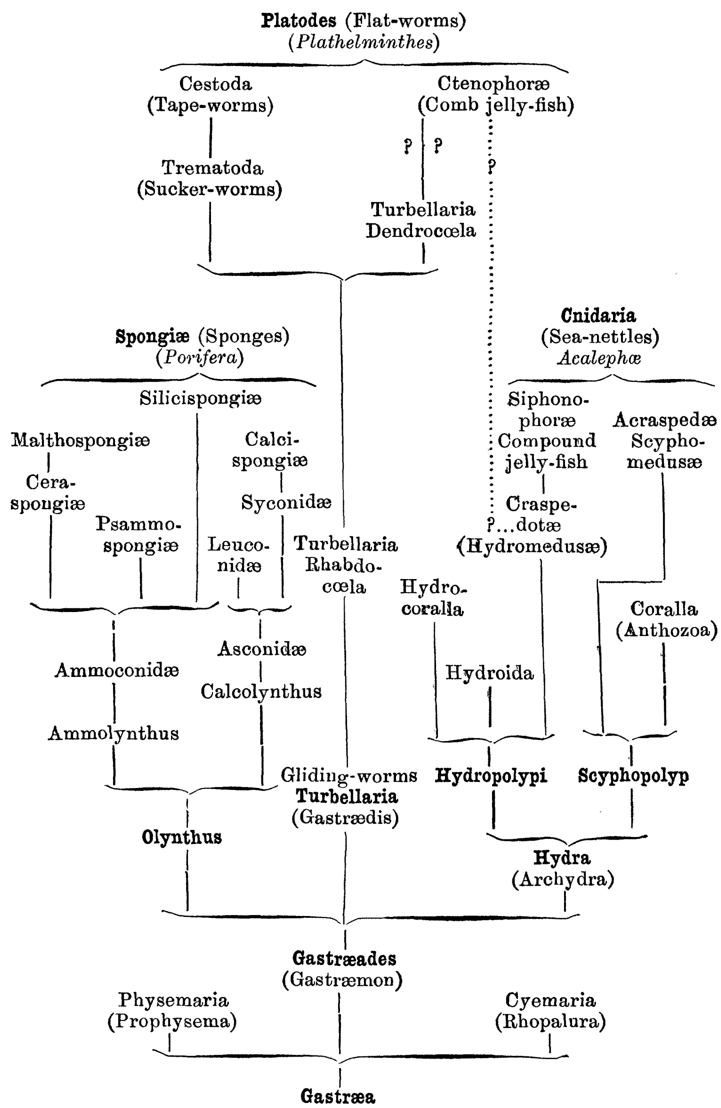
Some Medusæ attain a considerable size, as much as one metre in diameter and a weight of twenty kilograms. And yet their transparent, glass-like body consists only of from 3 to 6 per cent. (often of but 1 per cent.) of animal substance, and of from 94 to 99 per cent. of sea-water. The remarkable history of their lives, and especially the complicated alternation of generation of the Polyps and Medusæ, are among the strongest proofs of the truth of the theory of descent. For out of the eggs of the Medusæ there arise, as a rule, not Medusæ, but Polyps of the preceding class (Tubulariæ and Campanariæ). These latter, however, produce buds which detach themselves and become Medusæ. And just as, by this "change of generation," Medusæ still daily arise out of Polyps, so originally did the freely swimming Medusa-form proceed, phylogenetically, from the adherent polyp-form.

A careful examination of the Medusæ (a Monograph on which, with seventy-two coloured plates, I published in 1879) has proved that this group of animals, so rich in forms, is of polyphyletic origin; several different groups of Umbrella-jellies—quite independently of one another—have originated from several different groups of adherent Polyps. The primæval primary group of the Polyp tribe, the root of the whole Sea-nettle group, at an early date divided into two main lines: Hydropolyps and Scyphopolyps. The lower and more simply constructed *Hydropolyps* (or Bell-

SYSTEMATIC SURVEY

Of the Tribes and Classes of the Cœlenteria, or Low Animals.

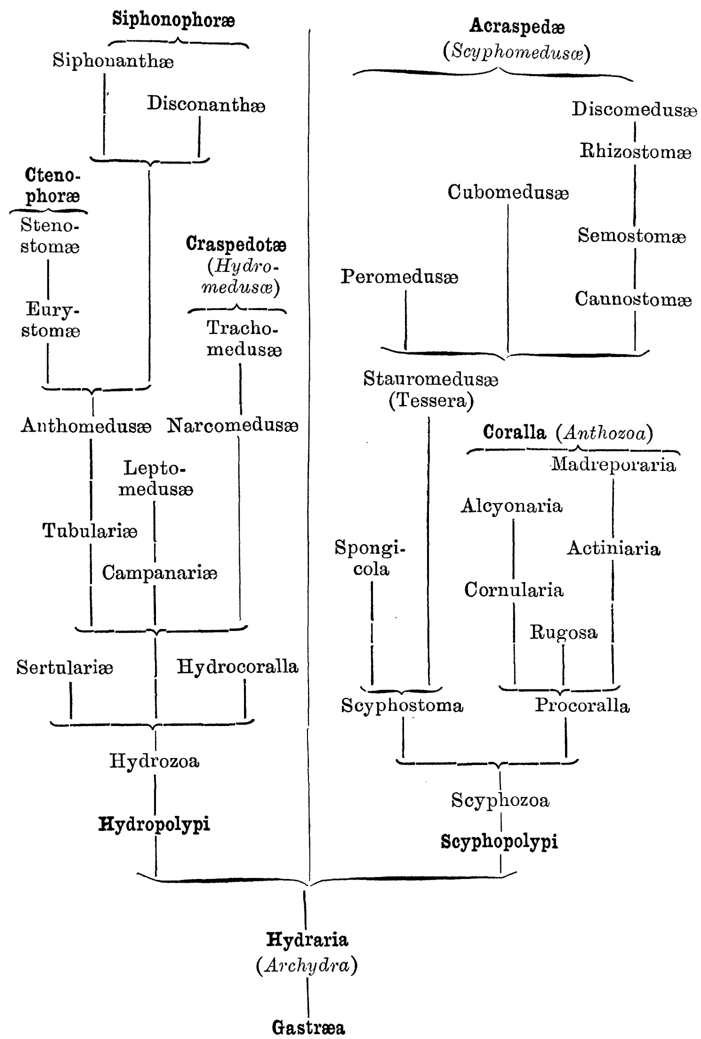
Tribes of the Cœlenteria.	*Character of the Four Tribes.*		*Classes of the Cœlenteria.*	*Generic Names as Examples.*
I. **Primary Intestine Animals. Gastræades.**	Cœlenteria without cutaneous pores, without tentacles, without nettle-organs. Fundamental form of one axis		1. **Gastræmones**	Gastræa.
			2. **Cyemaria**	Rhopalura.
			3. **Physemaria**	Prophysema.
II. **Sponges. Spongiæ** (or Porifera).	Cœlenteria with cutaneous pores, without tentacles, without nettle-organs. Fundamental form of one axis or irregular		1. Cementing Sponges **Malthospongiæ**	Ammolynthus. Euspongiæ.
			2. Flinty Sponges **Silicispongiæ**	Spongilla. Euplectella.
			3. Calcareous sponges **Calcispongiæ**	Ascon. Sycon.
III. **Sea-nettles. Cnidaria** (or Acalephæ).	Cœlenteria without cutaneous pores, with tentacles, with nettle-organs, without renal canals. Fundamental form rayed or pyramidal (with 4, 6, 8, or more cross axes), and a vertical main axis with unequal poles	III. A. Hydrozoa	1. Primary Polyps **Hydropolypi**	Hydra. Millepora.
			2. Veil jelly-fish **Craspedotæ**	Codonium. Geryonia.
			3. Compound jelly-fish **Siphonophoræ**	Porpita. Physalia.
			4. Comb jelly-fish **Ctenophoræ**	Cydippe. Beræ.
		III. B. Scyphozoa	5. Goblet polyps **Scyphopolypi**	Scyphostoma. Spongicola.
			6. Corals **Anthozoa**	Eucorallium. Madrepora.
			7. Lappet jelly-fish **Acraspedæ**	Periphylla. Aurelia.
IV. **Flat-Worms. Platodes** (or Plathelminthes).	Cœlenteria without cutaneous pores (mostly without tentacles, often with nettle-organs), with renal canals. Fundamental form, bilaterally symmetrical		1. Gliding-worms **Turbellaria**	Vortex. Planaria.
			2. Sucker-worms **Trematoda**	Distoma. Polystoma.
			3. Tape-worms **Cestoda**	Caryophyllæus. Tænia.


Platodes (Flat-worms)
(*Plathelminthes*)
Cestoda
(Tape-worms)
Ctenophoræ
(Comb jelly-fish)
? ?
?
Trematoda
(Sucker-worms)
Turbellaria
Dendrocœla
Spongiæ (Sponges)
(*Porifera*)
Cnidaria
(Sea-nettles)
Acalephæ
Silicispongiæ
Malthospongiæ
Cera-
spongiæ
Psammo-
spongiæ
Calci-
spongiæ
Syconidæ
Leuco-
nidæ
Turbellaria
Rhabdo-
cœla
Siphono-
phoræ
Compound
jelly-fish
Acraspedæ
Scypho-
medusæ
Craspe-
?...dotæ
(Hydromedusæ)
Hydro-
coralla
Coralla
(Anthozoa)
Ammoconidæ
Asconidæ
Calcolynthus
Hydroida
Ammolynthus
Gliding-worms
Turbellaria
(Gastrædis)
Hydropolypi
Scyphopolyp
Olynthus
Hydra
(Archydra)
Gastræades
(Gastræmon)
Physemaria
(Prophysema)
Cyemaria
(Rhopalura)
Gastræa

SYSTEMATIC SURVEY

Of the Classes and Orders of the Sea-nettles (Cnidaria).

Classes of Sea-nettles.	*Legions of Sea-nettles.*	*Orders of Sea-nettles.*	*A Genus as Example.*
I. **Polyps. Hydrusia.**	1. Hydropolyps **Hydropolypi**	1. Hydrariæ.	Hydra.
		2. Sertulariæ.	Plumularia.
	2. Coral-polyps **Hydrocoralla**	3. Milleporidæ.	Millepora.
		4. Stylasteridæ.	Stylaster.
II. **Umbrella jelly-fish. Medusæ.**	3. Veiled jelly-fish **Craspedotæ (Aphacellæ)**	5. Anthomedusæ.	Codonium.
		6. Leptomedusæ.	Æquorea.
		7. Trachymedusæ.	Aglaura.
		8. Narcomedusæ.	Ægina.
	4. Lappet jelly-fish **Acraspedæ (Phacellotæ)**	9. Scyphomedusæ.	Lucernaria.
		10. Peromedusæ.	Periphylla.
		11. Cubomedusæ.	Charybdea.
		12. Discomedusæ.	Aurelia.
III. **Compound jelly-fish. Siphonophoræ.**	5. Disc-shaped compound jelly-fish **Disconanthæ**	13. Disconectæ.	Discalia. Porpita. Velella.
	6. Tube-shaped compound jelly-fish **Siphonanthæ**	14. Calyconectæ.	Diphyes.
		15. Physonectæ.	Physophora.
		16. Auronectæ.	Rhodalia.
		17. Cystonectæ.	Physalia.
IV. **Comb jelly-fish. Ctenophoræ.**	7. Wide-mouthed **Eurystomæ**	18. Beroidæ.	Beröe.
	8. Narrow-mouthed **Stenostomæ**	19. Saccatæ.	Cydippe.
		20. Lobatæ.	Eucharis.
		21. Tæniatæ.	Cestum.
V. **Corals. Anthozoa.**	9. Cup-corals **Scyphopolypi**	22. Scyphostomida.	Scyphostoma.
		23. Spongicolida.	Stephanoscyphus.
	10. Fourfold corals **Tetracoralla**	24. Corallarcha.	Procorallium.
		25. Rugosa.	Stauria.
	11. Eightfold corals **Octocoralla**	26. Alcyonida.	Alcyonium.
		27. Tubulosa.	Tubipora.
		28. Gorgonida.	Eucorallium.
		29. Pennatulida.	Pennatula.
	12. Sixfold corals **Hexacoralla**	30. Antipatharia.	Antipathes.
		31. Actiniaria.	Actinia.
		32. Perforata.	Madrepora.
		33. Eporosa.	Astræa.


Siphonophoræ
Siphonanthæ
Disconanthæ
Cteno-phoræ
Steno-stomæ
Eury-stomæ
Craspedotæ (*Hydro-medusæ*)
Trachomedusæ
Anthomedusæ
Narcomedusæ
Lepto-medusæ
Tubulariæ
Campanariæ
Sertulariæ
Hydrocoralla
Hydrozoa
Hydropolypi
Acraspedæ (*Scyphomedusæ*)
Discomedusæ
Rhizostomæ
Cubomedusæ
Semostomæ
Peromedusæ
Caunostomæ
Stauromedusæ (Tessera)
Coralla (*Anthozoa*)
Madreporaria
Alcyonaria
Spongi-cola
Actiniaria
Cornularia
Rugosa
Scyphostoma
Procoralla
Scyphozoa
Scyphopolypi
Hydraria (*Archydra*)
Gastræa

polyps) retained the simple stomach-cavity of the primary form, and of the Gastræa. On the other hand, the *Scypho-polyps* (or Cup-Polyps) developed on the inner side of the stomach-wall projecting bands by which their peripheral cavity became divided into several (originally four) radial pouches. From these stomach-bands, or tæniola, there subsequently grew inner stomach-filaments, the mobile gastral filaments.

These two main lines of the Polyp pedigree correspond with two very different main groups of Medusæ, and, indeed, the latter originated out of the former in different ways, just as nowadays even their change of generation varies. The small and delicate veiled jelly-fish (*Hydro-medusæ* or *Craspedotæ*) arise out of Hydroid polyps by lateral budding. On the other hand, the large and splendid lappet jelly-fish (*Scyphomedusæ* or *Acraspeda*) develop out of Scyphopolyps by terminal budding. In both cases the characteristic swimming-organ of the Medusa, the muscular hood or umbrella, arises out of the oval disc of the polyps. But, in the Medusa, the adaptation to a freely swimming mode of life, and the consequent higher and more varied activity of the organs, causes these to become much more perfectly developed; the whole organization of the Medusa rises far above its low ancestral form, the polyp. The Medusa not only acquires a complicated vascular system for its nutrition, but also a nervous system and higher organs of sense, eyes, and auditory vesicle; these are still absent in its polyp progenitors.

Those who, like myself, have for many years studied the natural history of the splendid Medusæ, and their alternation of generation with the adherent polyps, may from this alone

even become firmly convinced of the truth of the Theory of Descent. For it alone can explain in the simplest manner the numerous and wonderful phenomena of the Medusæ, which without the doctrine of descent would be utterly inexplicable. In addition to this we must also specially remark that we find here a most clear instance of the so-called *convergence of forms, i.e.* of the development of similar forms from different primary roots (compare vol. i. p. 314). Certain Hydromedusæ (Narcomedusæ) so resemble some Scyphomedusæ (Cannostomæ) in their whole organization, that they were formerly classed in one group. And yet it can now easily be demonstrated that both are of utterly different origin. *Adaptation* to the same conditions of existence and the same mode of life has on various occasions here produced most similar forms of life, notwithstanding that inner characteristics transmitted by *Inheritance* prove their separate origin. The Hydromedusæ invariably lack the internal stomach or gastral filaments, which the Scyphomedusæ always possess.

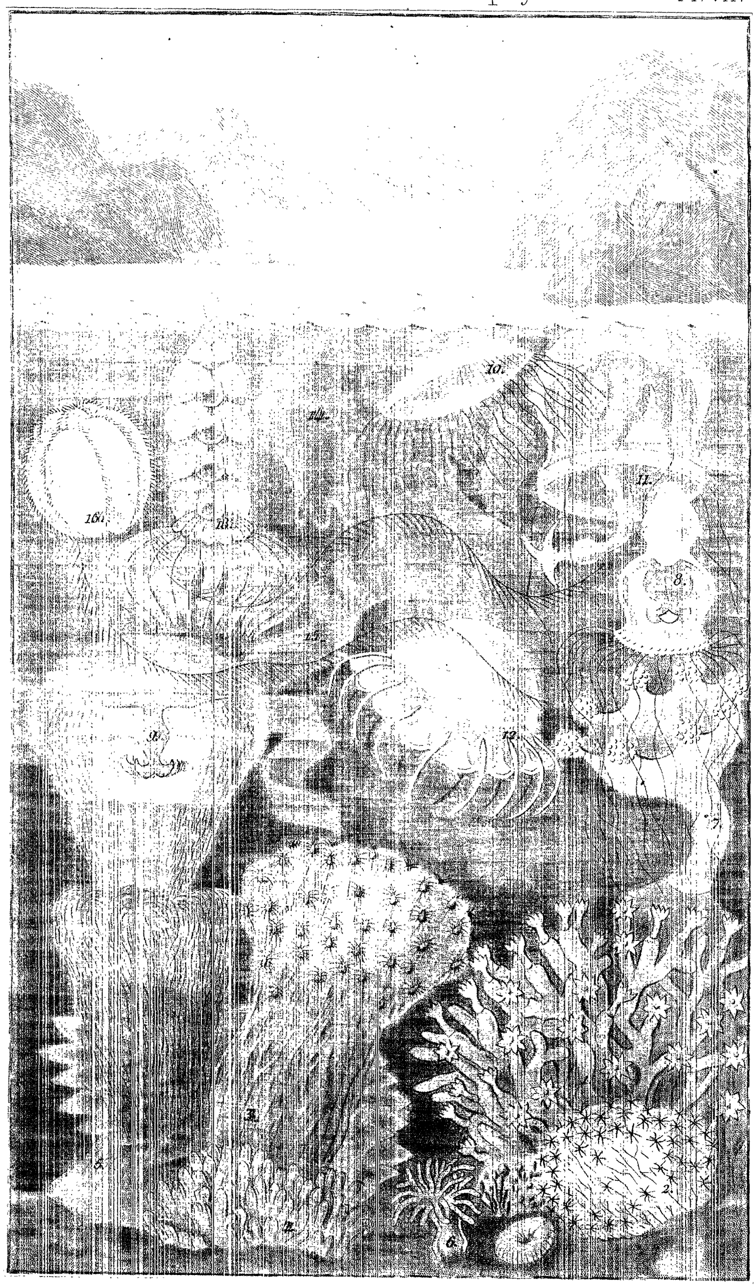
The origin of the other Sea-nettles can for the most part now also be clearly traced. Out of the two main branches of the tribe several classes have developed. The compound jelly-fish (*Siphonophoræ*)—and probably also the Comb jelly-fish (*Ctenophoræ*)—have proceeded from the division of the Hydromedusæ, and hence are originally descended from Hydropolyps. On the other hand, the primary forms of the corals, like those of the Scyphomedusæ, must be looked for among the Scyphopolyps.

One of the most beautiful and most remarkable classes of the whole animal kingdom—nay, perhaps the most splendid of all—is formed by the little known compound jelly-fish

(Siphonophoræ). These are swimming colonies of Hydromedusæ, whose delicate beauty and graceful movements are no less attractive than their exceedingly remarkable organization. They are best compared to swimming stocks of flowers, the pretty leaves, flowers, and fruit of which seem made of coloured glass. And yet all these different parts of the body are extremely sensitive and mobile. At the slightest touch the magnificently unfolded stock shrinks into a small lump. Careful examination shows us that every stock of Siphonophora is composed of a large number of different Medusa-like persons. Each of these medusæ has, by adaptation to a definite kind of life, assumed a peculiar form; some act as swimming-bladders, others as swimming-bells; a third group of persons, the Siphons, only take up and digest nourishment; a fourth group, the Palpons, have essentially the value of sensitive tractile organs; two other groups of persons, male and female. devote themselves exclusively to propagation—the former produce sperm, the latter eggs. Thus, in consequence of progressive *division of labour* and varied *change of labour* (see vol. i. p. 312), the different persons of the Siphonophora colony have developed quite differently and act together for the united life of the whole colony, in the same way as, among the higher animals, is done by the various organs of a single person, or like the different estates of a human community. In my treatise on "Division of Labour in Nature and in Human Life," I have discussed these most interesting circumstances in detail, and in their more comprehensive general significance.

During my sojourn on the Canary Islands, in 1866, I carefully studied the history of the development of the

Animal Plants or Zoophytes Pl. VII.



Siphonophoræ, and, as a result, brought forward the proof that an egg of these animals produced a simple Medusa-person; this Hydromedusa-larva produces, by budding, the numerous persons of the stock. The division of labour—or the *Adaptation* to separate functions—by which they assume different forms, has already been transmitted by *Inheritance* from the ancestors of the present Siphonophoræ. Further investigations on the natural history of these jelly-fish which I made later, and again during a visit to Ceylon in 1881, have considerably extended my knowledge of these most remarkable circumstances. It has been proved that this Sea-nettle class also is of *polyphyletic* origin; at least *two* different main groups of Siphonophora have developed, independently of each other, from several different groups of Hydromedusæ. The *Disconanthæ* (Discalia, Porpita, Velella) are probably derived from Trachomedusæ; the persons of the colony develop in this case by budding from the hood of the original Medusa (Pectyllide ?). On the other hand, the *Siphonanthæ* (Circalia, Rhodalia, Physalia) are certainly derived from Anthomedusæ; the persons of their colony develop by budding from the stomach-tube of the original medusa (Euphysid !). A more detailed explanation of this theory is given in my "System of the Siphonophoræ," and my detailed "Report of the *Challenger*-Siphonophoræ," which appeared a short time ago (1888), illustrated by fifty coloured plates.

But while the derivation of the Siphonophora has now become perfectly clear, that of another class of Sea-nettles, the Comb-jellies, or *Ctenophoræ*, is still quite obscure and doubtful. These jelly-fish, which are also frequently called Ribbed or Cucumber jellies, possess a cucumber-shaped body,

which, like the body of most Umbrella-jellies, is as clear and as transparent as crystal or cut glass. The Comb or Ribbed jelly-fish are characterized by their peculiar organs of motion, namely, by eight rows of padding, ciliated leaflets, which run in the form of eight ribs from one end of the longitudinal axis (from the mouth) to the opposite end. The internal organization of the Ctenophoræ is very peculiar; on the one hand, in many important points it resembles that of certain Hydromedusæ (*Cladonemidæ*); on the other, that of the Gliding-worms (*Turbellaria*), which we shall have to discuss presently. And with these two classes it is apparently connected by intermediate forms—with the former by *Ctenaria*, with the latter by *Ctenoplana*. Owing to this, some zoologists are at present more inclined to derive them phylogenetically from the Hydromedusæ, whereas others consider the Turbellaria to be their progenitors. According to a third opinion, they would be connecting intermediate forms between the former and the latter. However, it is probable, in this case also, that the striking resemblances are not the result of a common derivation from one and the same primary group, but the consequence of the *convergence* of forms. Further and careful investigations can alone explain the phylogeny of the Ctenophoræ.

The last class of Sea-nettles are the beautiful *Corals* (Coralla). They too, like all the other Cnidaria, are originally descended from simple Polyps, or Hydrusæ. The Coral animals live exclusively in the sea, and are represented, in the warm seas more especially, by an abundance of elegant and highly coloured forms like flowers. Hence they are also called *Flower-animals* (*Anthozoa*). Most of

them are attached to the bottom of the sea, and contain an internal calcareous skeleton. However, the body may also be perfectly soft and without any skeleton, as in the case of the Sea-roses (Actinia) which adorn our aquariums. Many Corals, by continued growth, produce such immense stocks that their calcareous skeletons have formed the foundation of whole islands, as in the case of the celebrated coral-reefs and atolls of the South Seas, the remarkable forms of which were first explained by Darwin. In Corals the radial pieces, or paramera—that is, the corresponding main divisions of the body which surround the central main axis body—exist sometimes to the number of four, sometimes to the number of six or eight. According to this we distinguish three legions: the Fourfold (Tetracoralla), the Sixfold (Hexacoralla), and the Eightfold Corals (Octocoralla). The Tetracoralla (Rugosa) are among the oldest petrified plant-animals, and are met with in numbers as early as the Silurian system. Probably this group represents the common primary form of the whole class. The two other legions probably developed out of simple Tetracoralla as diverging branches: the Octocoralla by the four paramera becoming doubled (the four stomach-pouches all dividing into two); the Hexacoralla by a divergence of the two cross axes,—the paramera of the one remaining simple, those of the other being doubled. The group of Octocoralla (or Alcyonaria) includes the well-known red corals (Eucorallium), and our northern Cork-corals (Alcyonium). The group of Hexacoralla (or Zoantharia) includes the soft Actiniæ and the main portion of the stone corals.

The fourth and last division of the Cœlenteria is formed by the Flat-animals (*Platodes*), also frequently called Flat-

worms (*Plathelminthes*). This interesting and important group contains three different classes: (1) the freely-living, ciliated *Gliding-worms* (*Turbellaria*); (2) the parasitical, naked skinned *Sucker-worms* (*Trematoda*); and (3) the parasitical *Tape-worms* (*Cestoda*) without body-cavity. All three classes are closely related, as is shown by the essential agreement in the inherited internal construction of their leaf-shaped body. They differ owing to peculiarities which have obviously been acquired by adaptation to different modes of life. The common primary group is formed by the Gliding-worms, which for the most part live in the sea; many live in fresh water also, only a few on land (in moist tropical forests). The simplest forms of these Turbellaria are closely allied to the Gastræades and Cnidaria. By adaptation to a parasitical mode of life, the Sucker-worms developed out of the Gliding-worms; in so doing the Sucker-worms lost their original garb of cilia, and acquired in its place instruments of seizure (sucking-cups and clasping-hooks). The *Tape-worms* have inherited these instruments from their ancestors the Sucker-worms, and have lost the alimentary canal which they possessed; owing to their locating in the intestine and in the tissues of other animals an alimentary tube became useless to them; the nutritive juice from their surroundings is admitted directly through the skin.

In three very important characteristics all Platodes agree with the other Cœlenteria, and differ from the Worms, or Helminthes, among which they are usually classed. In the first place, the Platodes have no body-cavity; secondly, no blood; and thirdly, no anus. The absence of these three important arrangements, so significant in the higher forms

of nutritive activity, must be regarded as existing *originally* in the Platodes, as in the case of the other Cœlenteria. Hence as early as 1872 (in my "Philosophy of the Calcareous Sponges," p. 465) I separated the Platodes as *Acœlomi* (Worms without body-cavity) from the *Cœlomati* (or the genuine Worms with body-cavity), and classed them with the Zoophytes, or Cœlenterata, as a much lower group.

On the other hand, the Platodes differ from the other Cœlenteria, and show themselves allied to the Helminthes by their bilateral fundamental form, as well as by possessing a pair of primary kidneys or nephridia. The bilateral or dipleurous fundamental form ("the bilateral-symmetrical type"), which occurs generally among the higher tribes of animals, appears so important for various reasons that we may group all of these latter together as *Bilateria* (*i.e.* animals with two sides or two halves), as opposed to the Radiata, or radiated animals. In all of these *Bilateria*—hence, in all Worms, Molluscs, Star-fish, Articulata, Tunicates, and Vertebrates—the body consists originally (in Man also) of two lateral halves (antimera), which are symmetrically alike. The right half, or right antimer, is the part opposite the left. In both halves we find the same organs in the same connection, and in the same relative but absolutely opposite position. Hence, in all Bilateria (in contrast to the Zoophytes), the position of all the various parts of the body is determined by three right axes, or euthynæ: the longitudinal axis, the dorso-ventral axis, and the lateral axis. The longitudinal, or main axis, runs lengthwise through the body of the person, from the front "mouth-pole" to the hinder "opposite mouth-pole." The dorso-ventral axis runs from the top to the bottom, from the

dorsal pole to the ventral pole. And, lastly, the lateral axis runs right across the body from the right to the left pole. The poles of this last-named axis are alike, whereas those of the two former are unlike. Hence we find originally in all Bilateria the distinction between right and left, back and front, whereas this distinction does not yet exist in most Plant-animals, or Cœlenteria. The great gulf to which this gives rise between the Cœlenteria and the Bilateria runs back perhaps as far as the common form of the Gastræa. In this case we should have to assume that the primary forms of the Platodes arose out of the Gastræades, independently of those of the Cnidaria, and that the bilateral forms of the Sea-nettles arose only secondarily.

It is obvious that this important difference in the *fundamental form* stands in causal connection with the original *form of locomotion* in animals. The earliest forms of Plant-animals adhered to the bottom of the sea, or they moved about freely in the water *without proceeding in any definite direction.* They would accordingly retain the fundamental form of one axis, such as was possessed originally by their ancestral form, the Gastræa of one axis (*Gastræa Monaxonia*); or they acquired a cross-axial, radiated, or radial fundamental form, as in the case of most Sea-nettles. The bilateral animals (Bilateria), on the other hand, moved about from the outset, either swimming in the sea or creeping about at the bottom, and moved *in a definite direction* which always remained the same. Thereby the original one-axial body of their Gastræa ancestors became bilateral, and even the earliest common primary form of the Platodes and Helminthes must have acquired this bilateral fundamental form; it possessed the three characteristic axes

described above, and thus became a *bilateral*, or rectaxial *Gastræa* (*Gastræa dipleura*).

The Platodes are further very strikingly different from the other Cœlenteria owing to the nature of that most important of all organs, the organ of the soul, or *central nervous system.* This organ has in their case always retained the original form, such as we must assume it to have had in the earliest primary group of the Bilateria—that is, a so-called primæval brain (Protoganglion), a simple nerve-cord from which radiate symmetrically lateral threads. Owing to its position above the mouth, or gullet, it is often also termed the supra-œsophageal ganglion (ganglion suprapharyngeum). This primæval brain developed originally out of a dorsal parietal plate on the outer surface of the skin-layer of the Gastræa dipleura, above the mouth. In most Worms also this primæval brain retains the same original, simple nature it has in the Platodes; only in a few groups is it more fully developed and forms a so-called gullet-ring. Among the Sea-nettles only one class shows a similar simple nerve-centre; these are the curious Comb-jellies already mentioned (Ctenophora), and as they also resemble the Platodes in other respects, and even appear related to them by direct intermediate forms, many zoologists now assume a direct phylogenetic connection between the two groups, and perhaps justly so.

A very important arrangement in the animal body is met with for the first time in the Platodes, namely, the renal tubes, or nephridia, frequently also termed "water-vessels or organs of excretion." They serve for emitting useless juices from the body, and thus correspond with the urinary

organs or kidneys of the higher animals. Now, as these are always absent in the Cnidaria and the Spongiæ, and always met with in the Platodes, we may assume that they appeared first in the earlier primary forms of this phylum. The Platodes have transmitted them, by inheritance, to the Helminthes, and the latter have transmitted them to the higher tribes of animals. It is probable that the nephridia were originally only enlarged skin-glands. In the Platodes they usually show themselves in the form of a couple of simple tubes or branching canals, lying on both sides of the intestine, and opening outwardly at one point.

Leaving now the large realm of the Cœlenteria or Cœlenterata, we pass over into the second great kingdom of the Metazoa, into the domain of the Cœlomaria or Bilaterata, with its wealth of forms. As has already been stated on several occasions, the Cœlomaria are distinguished from the Cœlenteria first of all by possessing a *body-cavity* (*Cœloma*) —a hollow space altogether separate from the intestine, and enclosing a portion of it. Further, the Cœlomaria (with the exception of a few groups) possess *blood*, and most of them special blood-vessels. Lastly, in most Cœlomaria, the intestine has two openings—a mouth and an anus; in the various groups where the anus is wanting, it has obviously been lost by degradation.

For many important reasons we may assume that the *Cœlomaria are derived from Cœlenteria*, and, indeed, from the last-mentioned fourth group, the Platodes; of these the *Turbellaria* of to-day stand closest to the extinct primary forms of the Cœlomaria. These latter, by inheritance, have retained the bilateral fundamental form of the former, and this justifies their being classed as Bilateria (see above,

p. 191). Further, this unknown primary form, or the intermediate link between the Turbellaria and the Cœlomaria, inherited from the former another important characteristic feature, namely, the primæval brain (or the supra-œsophageal ganglion) and a pair of nephridia or renal tubes.

The six higher tribes of the animal kingdom, which form our sub-kingdom of the Cœlomaria, are now universally classed, phylogenetically, as first grouped by me twenty years ago; that is, the tribe of Worms (Helminthes) is regarded as the common primary group, out of which the five higher types have developed. The latter appear even nowadays connected in so many ways with the former by transition forms, and by the closest ontogenetic circumstances, that this interpretation is almost universally accepted. On the other hand, the opinions of zoologists are very far from being unanimous with regard to the question how the closer relationships between the five higher animal tribes are to be conceived. In my opinion, the most probable solution to the question is that they arose independently of one another from different branches of the great tribe of Helminthes, somewhat as described in the hypothetical pedigree given on p. 181.

The tribe of *Worm-like Animals* (*Helminthes*)—or, as they are often briefly termed, the Worms, Vermes, or Verminosa—is one of quite peculiar interest, for the reasons we have given above; it forms, on the one hand, the root-group of the Cœlomaria which arose out of the Platodes, and on the other hand forms the common primary group out of which the five higher tribes of the animal kingdom have developed. I regard the domain of this important tribe as much more limited than is usually done; on the one hand I

remove the Platodes, which I place among the Cœlenteria; and on the other hand remove the Annelids, which I class among the Articulata. By this means it becomes possible more sharply to define the difficult primary group of the Helminthes, and to classify them by definite characteristics. The Worm tribe is distinguished on the one hand from the Platodes, by possessing a body-cavity, blood, and an anus; and on the other from the five higher tribes of animals, by the want of the positive characters by which the latter are all distinguished (see above, p. 180). More especially, all animals classed as Helminthes are *inarticulated Bilaterata*, with simple nerve-knot or gullet-ring; they invariably lack the mantle formation and radula of the Molluscs, the ambulacral and nervous systems of the Echinoderma, the segmented ventral nerve-cord of the Articulata, the cord and medullary tube of the Tunicates and Vertebrates.

The ten classes into which I here divide the tribe of Helminthes may be subdivided into four cladomes, or main classes: 1. The Wheel-worms (*Rotatoria*); 2. Round-worms (*Strongylaria*); 3. Snout-worms (*Rhynchocœla*); and 4. Arm-worms (*Prosopygia*). How the obscure phylogeny of these groups may approximately be conceived of is shown in the pedigree on p. 181. We will now only very briefly mention the classes, for their relationships and derivation are at present still very complicated and obscure. More numerous and more accurate investigations on the ontogeny of the Helminthes will at some future time throw more light upon their phylogenesis.

The first cladome of the Helminthes is formed by the *Wheel-animalculæ* in the widest sense (*Rotatoria*). They may also be termed the Primæval Worms (Archelminthes),

because the class probably includes the extinct common primary form of the Worm-like animals. This "primæval worm" (Prothelmis)—descended from the simplest rhabdocœl Turbellaria—we imagine to have been a most simple in-articulated worm with a garb of cilia, and that its simple intestine possessed a mouth and anus; above the mouth a simple or double cerebral knot (parietal plate); a pair of nephridia or renal tubes opening into the simple body-cavity. Our present Ichthydina (*Gastrotricha*), fresh-water animalcules, seem to be very closely related to this hypothetical primæval worm. Another closely allied form is the *Trochophora*, the important larval form which is met with, ontogenetically, in various modifications in very different classes of Cœlomaria, probably the hereditary remnant of a corresponding phylogenetic primary group (*Trochozoa*). A somewhat higher development is manifested by the true Wheel-animalcules (in a narrower sense), the *Rotifera*. They are very small, nearly microscopic animals, for which reason they were formerly erroneously classed among the true Infusoria. In fresh water, more especially, they are very widely distributed; they swim about by means of a peculiar ciliated apparatus, the so-called "wheel-organ." This wheel-organ is met with in the form of "ciliated bands and fringed sails," etc., both in the larvæ or youthful forms of many other Helminthes, as well as in the young larvæ of the higher tribes of animals. Their primordial ancestral forms, which developed, in the first place, from Worm-like animals, therefore perhaps possess a close phylogenetic relationship to the Rotatoria. Other zoologists regard this group as a degenerate one, and attach no palingenetic importance to this similarity of the different "wheel-organs."

The second cladome of the Helminthes embraces the extensive division of the *Round-worms* (*Strongylaria* or *Nematelminthes*), which are characterized by their tough non-ciliated skin, a round, long-extended cylindrical shape of body which is of the most simple construction. They live for the most part as parasites in the interior of other animals and plants, and are very widely distributed. Of human parasites, the celebrated Trichinæ, the Maw-worms (Ascaris), the Whip-worms (Trichocephalus), Thread-worms (Filaria), for example, belong to them. In addition to the genuine Round or Thread-worms (Nematoda), this main class also includes the parasitical *Gordiaceæ*, which have partially lost their intestinal tube; and the *Acanthocephala*, which have entirely lost it owing to their parasitical mode of life (like the Tape-worms). The strange *Arrow-worms* (*Chætognathi*) also, which swim about in immense numbers on the surface of the sea, are often classed with them; however, owing to their peculiar structure, they stand pretty well apart, and already show signs of a higher organization. The origin of the body-cavity from a pair of cœlomic pouches, which grow out of the intestine, and become pinched off from it, can be very clearly observed in these Arrow-worms, or Sagitta (compare Plate V., Fig. 19, 20).

The third main class of Helminthes, the *Snout-worms* (*Rhynchocœla* or *Rhynchelminthes*), must be regarded as a very ancient and phylogenetically important group. It comprises the Nemertina and the Enteropneusta, two rather different classes, both of which, however, are characterized by peculiar snout-formations, and show peculiar affinities to the Echinoderma and the Chordonia (Tunicates and Vertebrates). The class of *Cord-worms* (*Nemertina*) contains

numerous worms which mostly live in the sea, with long flattened bodies, often tape-shaped. They were formerly reckoned among the Platodes, but rise far above these Cœlenteria by possessing blood-vessels and an anal orifice. The class of *Tongue-worms* (*Enteropneusta*) contains only a single genus of worms, but a very remarkable one, which lives buried in the sea-sand (Balanoglossus). Owing to its curious branchial gut, it appears to be the last remnant of those Helminthes from which the Chordonia (Tunicates and Vertebrates) are derived.

The fourth and last cladome of the Helminthes is formed by the Arm-worms (*Prosopygia* or *Brachelminthes*). It is composed of four classes, all of which agree in the characteristic formation of the intestine and in possessing tentacles or arms at the mouth. Two of these four classes (Bryozoa and Brachiopoda) were formerly erroneously classed among the Molluscs, and very inappropriately termed Molluscoidea. The Sea-mosses (Bryozoa) are a class rich in forms, the elegant stocks of which (mostly living in the sea) greatly resemble stocks of polyps. The marine spiral-gilled animals (*Brachiopoda*) possess a bivalved calcareous case, somewhat like a shell; masses of them are found petrified in the oldest mountains containing fossils, and they are of great importance to geology as "guiding-shells." The two other classes, which Arnold Lang, in his excellent manual on Comparative Anatomy, classes with the two former as "Prosopygia," are the marine *Horseshoe-worms* (*Phoronea*) and the *Squirt-worms* (*Sipunculea*). Formerly they were classed sometimes with the Echinoderma, sometimes with the Articulata.

The great tribe of Worm-like Animals (Helminthes), with

SYSTEMATIC SURVEY

Of the Cladomes and Classes of the Helminthes.

Cladome or Main Classes.	*Classes of the Helminthes.*	*Name of Genus as Example.*	*Special Remarks.*
I. Cladome: Wheel-worms **Rotatoria** (*Archelminthes*)	1. Prothelminthes *Trochozoa* 2. Gastrotricha *Ichthydina* 3. Wheel-animalcule *Rotifera*	Prothelmis, Trochosphæra Chætonotus, Ichthydium Philodina, Hydatina	Skin delicate, with ciliated organs. Intestine simple, straight anus posteriorly. (Phylogenetic connections with the Platodes.)
II. Cladome: Round-worms **Strongylaria** (*Nemathelminthes*)	4. Thread-worms *Nematoda* 5. Hook-headed worms *Acanthocephala* 6. Arrow-worms *Chætognathi*	Trichina, Ascaris Echinorhynchus, Acanthocephalus Sagitta, Spadella	Skin hard, without ciliated organs. Intestine simple, straight, anus behind. (Phylogenetic connections with the Articulata.)
III. Cladome: Proboscideans **Rhynchocœla** (*Rhynchelminthes*)	7. Cord-worms *Nemertina* 8. Tongue-worms *Enteropneusta*	Polia, Nemertes Tornaria, Balanoglossus	Skin soft, with cilia-covering. Intestine straight; in front a proboscis, anus behind. (Phylogenetic connections with the Chordonia.)
IV. Cladome: Arm-worms **Prosopygia** (*Brachelminthes*)	9. Sea-mosses *Bryozoa* 10. Spiral-gilled animals *Brachiopoda* 11. Horseshoe-worms *Phoronea* 12. Squirt-worms *Sipunculea*	Loxosoma, Flustra Lingula, Terebratula Actinotrocha, Phoronis Sipunculus, Priapulus	Skin soft, mostly enclosed in cases or tubes. Intestine horseshoe-shaped. Anus beside the mouth. Tentacles or arms all round the mouth. (Phylogenetic connections with the Molluscs.)

its wealth of forms, has hitherto been regarded as the dreaded "lumber-room of zoology," into which were thrown all the lower animals about which little was known, or which for some reasons could not be classed with others. However, it gains greatly in morphological clearness and phylogenetic interest, when its domain is somewhat more sharply defined in the manner here done. When the Platodes are set apart on the one hand, and the Annelids on the other, there remain only the four cladomes, all of which agree in the most important morphological characteristics. In this limitation the tribe of the Helminthes appears as an exceedingly interesting intermediate group, a connecting link between the Cœlenteria (Platodes) on the one hand, and the higher tribes of animals on the other. The latter have developed as diverging branches out of the many-branched tribe of Worms, whereas its root must be looked for among the Platodes.

In judging of the phylogeny of the Helminthes, special care and critical reservation are therefore necessary, for, as regards most classes of the tribe, we are absolutely without any palæontological records. We are accordingly almost exclusively confined to the records of comparative anatomy and ontogeny; and these, in the present case, often seem contradictory. Besides, there are often great gaps between many of the various classes and families. All the living groups of Helminthes seem no more than separate little twigs of some mighty tree which, in the grey past of primordial times, developed a number of mighty branches with numerous offshoots. By far the larger portion of these have long since died off, without having left the remotest trace of their existence.

CHAPTER XXII.

PEDIGREE AND HISTORY OF THE MOLLUSCS AND STAR-FISHES.

Tribe of Molluscs.—Their Organization.—Relationship between the Three Main Classes.—Primary Group of Snails (Cochlides).—Origin of Mussels (Acephala) by Degeneration of the Head.—Development of Cuttles or Poulps (Cephalopoda) by the further Formation of Head and Arms.—Tribe of Star-fishes, or Echinoderma.—Their Organization.—Bilateral Five-rayed Fundamental Form.—Water-channel System.—Ontogeny.—Hypotheses on the Phylogeny of the Echinoderma.—The Pentastræa Hypothesis (1866).—Derivation of all Star-fishes from Sea-stars, and of these latter from Articulated Worms (Mailed Worms or Phracthelminthes.—The Three Main Classes of Echinoderma.—Astrozoa (Sea-stars and Sea-rays).—Pelmatozoa (Sea-lilies, Sea-buds, and Sea-apples).—Echinozoa (Sea-urchins and Sea-cucumbers).—The Pentactæa Hypothesis of Semon (1888).—Phylogenetic Importance of the Common Ontogenetic Larva-form: Pentactula.

THE great natural main groups of the animal kingdom, which we have distinguished as tribes or phyla, are not all of equal importance for our phylogeny or the history of the pedigree of the living world. They can neither be classed in a single series of stages, one above the other, nor be considered as entirely independent stems, nor as equal branches of a single family tree. It seems rather, as we have seen in our last chapters, that the *Gastræa* presents itself as the common primary form of all the Metazoa. This primæval,

radical form of Gastræa—of whose former existence we have, even nowadays, tangible evidence in the *Gastrula* germinal form of the most different animals—produced in the first place a number of different *Gastræades;* and these, owing to their primitive organization, we have considered as the simplest *Cœlenteria* or *Plant-animals.* Out of the Gastræades the rest of the Cœlenteria were subsequently developed, on the one hand the Sponges and Sea-nettles, on the other the Flat-animals (Platodes). And the latter gave rise to the Worm-like animals, the Helminthes. This tribe, with its far-reaching branches and great variety of forms, we must again regard as the common primary group, out of which (from perfectly different branches) the other tribes, the higher phyla of the animal kingdom, have shot forth (compare the hypothetical pedigree on p. 165).

It is a matter of no importance whatever in what succession we take up the examination of the higher tribes of the animal kingdom. For these phyla have no close relationship whatever among one another, but have grown out of entirely different branches of the group of Worms. The *Molluscs* may be considered the most imperfect and the lowest of these phyla, at least as regards morphological development. The tribe of Molluscs comprises three main classes or cladomes: the Snails (*Cochlides*), the Mussels (*Conchades*), and the Cuttles (*Teuthodes*). The Snails form the main portion and are the primary group of the Mollusca tribe. Out of them arose the *Mussels* by degeneration, the *Cuttles* by progression.

The characteristic feature of all Molluscs is the *inarticulated,* sack-shaped body; the muscular surface of the belly forms a foot, used for creeping about, which varies in shape,

but is generally flat like the sole of a shoe, whereas the skin of the arched surface of the back rises all round in the form of a mantle-shaped fold, the so-called *mantle*. The fundamental form of the body, transmitted by inheritance from its worm-ancestors, is *bilaterally symmetrical;* still frequently striking *asymmetrical* forms are developed, and the right side of the body appears much larger than the left, or *vice versâ*. Between the rim of the foot and the rim of the mantle there is originally a cavity in which lie the *gills* used for breathing. We nowhere meet with any definite segmentation of the body, articulation, or formation of metamera, which, in the three tribes of the Echinoderma, Articulata, and Vertebrata, is the most essential cause of the higher development of forms and of their higher perfection generally. In fact, in all Molluscs, in all Mussels, Snails, etc., the entire body is a simple non-jointed sack, in the cavity of which lie the intestines. It is only the foremost part of the body that, as a head, stands more or less distinctly apart from this non-jointed trunk. In most Snails this head is moderately developed, and possesses a pair of eyes and a pair of feelers or tentacles, also a mouth with jaw and teeth and a tongue like a many-toothed rasp. In the Mussels the head has degenerated, whereas in the Cuttles it is very highly developed.

The nervous system of the Molluscs is very characteristic, and consists originally of a gullet-ring, from which proceed two pairs of strong lateral nerve-cords (*Amphineura*). Usually, however, they are so developed that an upper primary brain or cerebral ganglion is connected, by means of a front gullet-ring, with the pedal ganglion lying below, and by means of a back gullet-ring with a gill-nerve-cord

lying behind. In the large majority of Molluscs the soft, sack-shaped body is protected by a *calcareous shell*, or house, a hardened excretion of the mantle. Originally this shell, or "conchylia," is a flat shield or bowl covering the back. In most Snails it grows into a spirally twisted tube, forming the well-known "snail's house." In the Mussels, however, it develops into two lateral valves, attached at the back by an elastic ligament. Molluscs, owing to possessing these solid calcareous shells, are also called Shell-fish (*Conchylia*)—the *Ostracoderma* of Aristotle. Although they are found petrified in masses in all the Neptunian strata, they do not instruct us much about the historical development of the tribe. For this occurred for the most part in the earlier primordial period. Even in the Silurian strata we find petrifications of all the three main classes of Molluscs side by side, and this—in agreement with many other testimonies—distinctly proves that the tribe of Molluscs had attained a vast development, at a time when the higher tribes, more especially the Articulata and Vertebrata, had scarcely got beyond the beginning of their historical development. In the succeeding periods, especially, at first in the Primary, and afterwards in the Secondary period, the higher, articulated tribes of animals became more and more widely distributed, at the expense of the non-articulated Molluscs and Worms; the latter were not their equals in the struggle for existence, and had, accordingly, to give way more and more. The still living Molluscs and Worms have to be regarded as a comparatively small remnant of the extensive fauna which greatly predominated over all other tribes during the Primordial and Primary epochs. The great majority of the present Molluscs

live in the sea, a much smaller number in fresh water; and of those living on land we have only Snails with lungs (Pulmonata).

In no class of animals is it more evident than in that of the Molluscs how very different the value of fossils is in geology and in phylogeny. In geology the various species of fossilized mollusca-shells are of the utmost importance, because, as "guiding shells," they render admirable service in the characterization of the different groups of strata and in fixing their relative ages. Nevertheless, they are of but little value to the phylogeny of the Molluscs, on the one hand because as bodily parts they are of very subordinate morphological importance, and on the other because the actual development of the tribe occurs in the Primordial epoch, from which no distinct fossils have been preserved. Many Snails with similar shell-formations possess an entirely different internal organization, and *vice versâ.* Hence, in constructing the pedigree of Molluscs, we are mainly dependent on the records of comparative anatomy and ontogeny, and these lead to a result somewhat as is given on p. 209.

The main class of *Snails* (*Cochlides*) must be regarded as the actual main or primary group of Molluscs. Out of them the Mussels probably developed by retrograding, the Cuttles by progressive transformation; the head was lost by the former, whereas it became more highly developed in the latter. The main class of Snails is divided into several sub-classes rich in forms; in spite of very different and various kinds of development, they nevertheless (by their common youthful form) appear to be closely related descendants of one primæval primary form. This hypothetical

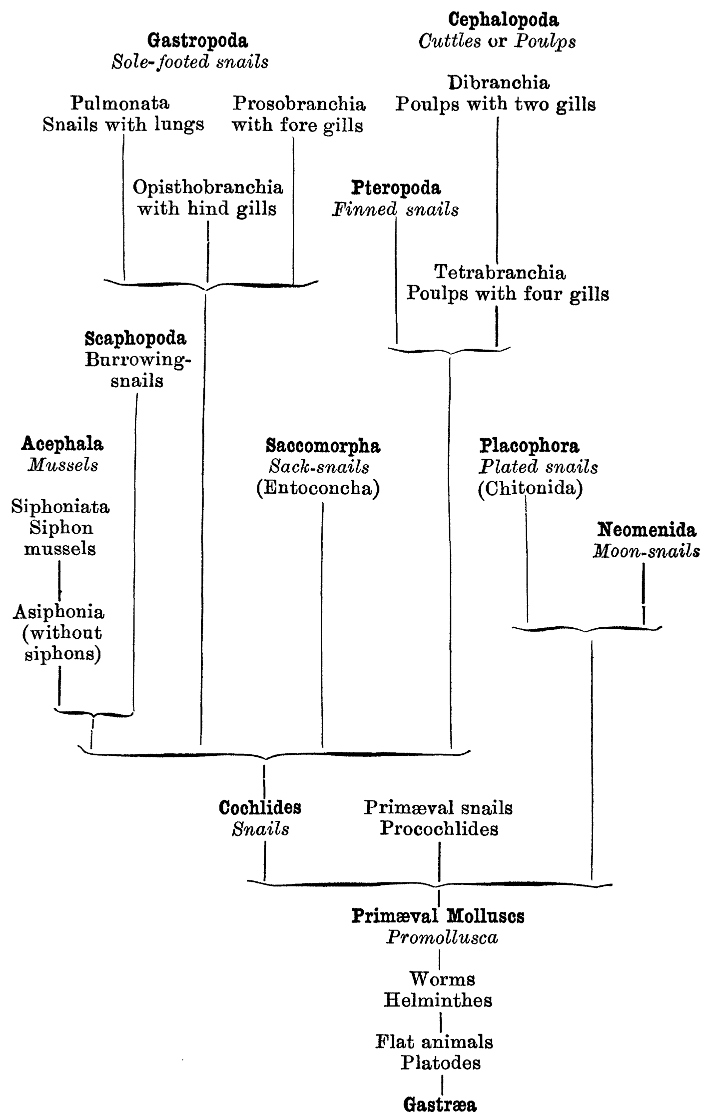
primary form, extinct now for millions of years, the *primæval Snail* (*Procochlis*), we may imagine as an intermediate form between the lowest still living snails (*Amphineura*) and the non-articulated Helminthes. Their ontogeny would have shown the interesting Sail-larva (*Veliger*), which still appears as a transitory form in the ontogeny of most Molluscs. The Sail-larva takes its name from a large, ciliated bivalved "sail" or "wheel-organ" (*Velum*), which appears on the forehead of the young mollusc, the back being covered by a small bowl-shaped shell. It can be directly traced from the *Trochophora* of the Helminthes.

Either the worm-like *Neomenida* (*Neomenia*, *Chæto-derma*) or the closely related *Placophora* (Chiton) may be regarded as the oldest molluscs of the present day, and, accordingly, as standing nearest to the common primary form of the Mollusca. These Placophora, or Plate-shaped Snails, are nowadays generally considered a separate class, characterized by the shell on the back being divided into eight calcareous plates lying one behind the other. The Snails with a pair of gills (*Zeugobranchia*), which are regarded as belonging to the large class of *Sole-shaped Snails* (*Gastropoda*), stand closer to the Placophora by the primitive nature of the internal structure of their body, than any of the other Snails. Their foot is a flat sole, by means of which the animal creeps about, as in the case of our common land-snails. The Gastropoda are divided into three main divisions: the Prosobranchia, the Opistho-branchia, and the Pulmonata. In the Prosobranchia the gills are in front of, in the Opisthobranchia they are behind, the heart. In the Pulmonata—to which class belong our

SYSTEMATIC SURVEY

Of the Classes and Orders of Molluscs (Mollusca).

	Classes of Molluscs.	*Orders of Molluscs.*	*Subdivisions of Molluscs.*	*Name of Genus by way of Example.*
I. *Cochlides.*	I. **Primæval Molluscs** *Promollusca*	1. Primæval snails *Procochlides*	1. Procochlides	Procochlis
			2. Neomenida	Neomenia
		2. Flat-snails *Amphineura*	3. Placophora	Chiton
	II. **Sole-footed Snails** *Gastropoda*	3. With fore gills *Prosobranchia*	4. Chiastoneura	Fissurella
			5. Orthoneura	Murex
			6. Heteropoda	Carinaria
		4. With hind gills *Opisthobranchia*	7. Tectibranchia	Aplysia
			8. Nudibranchia	Doris
			9. Saccoglossa	Elysia
		5. Snails with lungs *Pulmonata*	10. Branchiopneusta	Lymnæus
			11. Nephropneusta	Helix
	III. **Burrowing Snails** *Scaphopoda*	6. Burrowing-snails *Scaphopoda*	12. Dentalida	Dentalium
II. *Conchades.*	IV. **Mussels** *Acephala*	7. Mussels without respiratory tubes *Asiphonia*	13. Palæoconchæ	Arca
			14. Monomyaria	Ostrea
			15. Najades	Unio
		8. Mussels with respiratory tubes *Siphoniata*	16. Disiphonia	Tellina
			17. Gamosiphonia	Solen
			18. Inclusa	Teredo
	V. **Sack Snails** *Saccomorpha*	9. Sack-snails *Saccomorpha*	19. Entoconchida	Entoconcha
III. *Teuthodes.*	VI. **Finned Snails** *Pteropoda*	10. Finned snails *Pteropoda*	20. Propteropoda	Conularia
			21. Thecosomata	Hyalæa
			22. Gymnosomata	Clio
	VII. **Cuttles** or **Poulps** *Cephalopoda*	11. Ink-poulps with four gills *Tetrabranchia*	23. Proteuthides	Orthoceras
			24. Polyolenæ	Nautilus
		12. Ink-poulps with two gills *Dibranchia*	25. Decolenæ	Sepia
			26. Octolenæ	Octopus


Cephalopoda
Cuttles or Poulps
Gastropoda
Sole-footed snails
Pulmonata
Snails with lungs
Prosobranchia
with fore gills
Dibranchia
Poulps with two gills
Opisthobranchia
with hind gills
Pteropoda
Finned snails
Tetrabranchia
Poulps with four gills
Scaphopoda
Burrowing-
snails
Acephala
Mussels
Siphoniata
Siphon
mussels
Asiphonia
(without
siphons)
Saccomorpha
Sack-snails
(Entoconcha)
Placophora
Plated snails
(Chitonida)
Neomenida
Moon-snails
Cochlides
Snails
Primæval snails
Procochlides
Primæval Molluscs
Promollusca
Worms
Helminthes
Flat animals
Platodes
Gastræa

common vineyard snails (*Helix*) and garden snail (*Limax*)—the gill-cavity, by adaptation to breathing air, has changed into a lung-cavity. These Snails with lungs are the only Molluscs which have forsaken the original life in water, and adapted themselves to a life on land.

One of the most remarkable forms of Molluscs is the little parasite, Entoconcha mirabilis, which forms the special class of the Sack-snails (*Saccomorpha*). This Entoconcha mirabilis was discovered by the eminent Berlin zoologist, Johannes Müller, in the bay of Muggia, near Triest. In its mature state it forms a simple sack or pouch filled with eggs and sperm, and is found attached to the intestine of a sea-cucumber (Synapta). Never would it have been supposed that this simple bag of eggs was a transformed snail, had it not been that the eggs developed into young snails, which perfectly resemble the Sail-larvæ (Veliger) of common gilled snails (Natica), and possess a ciliated sail and a shell. It is obvious that, owing to having adopted a parasitical mode of life, the snail has become so degenerated that by degrees it has lost all its original organs, except skin and sexual organs. This case stands as a solitary one among the Molluscs, whereas among the Crustacea it is very often met with in the sack-crabs (Sacculina). Ontogeny alone gives an explanation of the origin and family history of these utterly degenerate parasites.

It is probably likewise owing to degeneration—which, however, has especially affected the head—that *Mussels* (*Conchades*) have arisen out of a group of Snails. On account of the want of a head, the Mussels are often also called *Acephala*, or, again, *Lamellibranchia*, owing to their leaf-shaped gills. Other zoologists call them *Pelecypoda*, on

account of their hatchet-shaped feet; or, again, *Bivalva*, on account of their bivalved shells. All Mussels have lost the head, and hence also the jaws and the characteristic toothed plate of the tongue (Radula) which is met with in all other Mollusca (with the exception of the degenerated Entoconcha mirabilis). The cause of this great retrogression must probably be attributed to adaptation to an adherent mode of life; even at the present time many Mussels adhere to the bottom of the sea, some grow to it by means of their shell (Oysters), some by means of the byssus, a peculiar bundle of fibres that grow out of one of the glands of the foot (the common mussel and horse-mussels). All Mussels have also forfeited the two eyes of the head; however, many Mussels have replaced these by acquiring a large number of new eyes, which are placed in a long row on both edges of their wide mantle. The originally simple shell on the back of the Snails has fallen into three pieces in the Mussels—the two valves at either side, and one the elastic ligament which runs along the back and joins and keeps together the two valves in a "lock" or joint.

Our phylogenetic hypothesis, that the Mussels have arisen out of a group of Snails by degeneration and loss of the head, is confirmed both by comparative anatomy and ontogeny, as well as by the circumstance that there still exists a connecting intermediate form; this is the genus *Dentalium*, which forms the special class of the Burrowing-snails (*Scaphopoda*). To these the Burrowing-clams are closely related, and, like the Razor-shells and Venus-shells, belong to the order of the Siphoniata. In these *Siphoniata* there are developed respiratory tubes, which are wanting in the *Asiphonia*. These latter include the Oysters, mother-

of-pearl Shells, and also our common fresh-water Mussels, or Najades.

A peculiar class of Molluscs is formed by the Butterfly Snails (*Pteropoda*), nocturnal marine animals, which inhabit the oceans in great masses, and are the principal food of Whales. By means of two large flaps or wings on the head (which have originated by the transformation of the foremost part of the foot) they flutter about in the sea like butterflies. In many respects they form the transition from Snails to the *Cuttles* (*Teuthoda*), and are classed among them by some zoologists. The main mass of these Teuthoda forms the curious class of Ink-fish or Head-footed fish (*Cephalopoda*)—a class which even Aristotle had examined. All of these, likewise, live in the sea. Owing to their larger size and more perfect organization—especially the high development of the large head—the Cephalopoda stand considerably above the Snails, although they are undoubtedly derived from them. They are distinguished from Snails by possessing eight, ten, or even more long arms encircling the mouth, and thus presenting a peculiar shape of head (like that of the Finned Snails). The Cuttles existing in our present oceans—the Sepia, calamary, argonaut, and pearly nautilus—are but a poor remnant of the host which represent this class in the oceans of the primordial, primary, and secondary periods. The numerous fossilized "Ammon's horns" (Ammonites), "pearl boats" (Nautilus), and "thunderbolts" (Belemnites) are evidences of the long-since extinct splendour of the tribe. Most of the extinct Cuttles belong to the legion with *four gills* (*Tetrabranchia*), of which now the only survivor is the "pearl-boat" (Nautilus). All the

other Cephalopoda of the present day belong to the legion with *two gills* (*Dibranchia*).

The different orders distinguished among the classes of Molluscs (the systematic succession of which I have given in the preceding table, p. 208) offer, by their historical and corresponding systematic development, manifold proofs of the validity of the law of progress. As, however, these subordinate groups of Molluscs are of no special interest in themselves, I refer my readers to the sketch of their pedigree on p. 209, and now turn to the consideration of the tribe of Star-fishes.

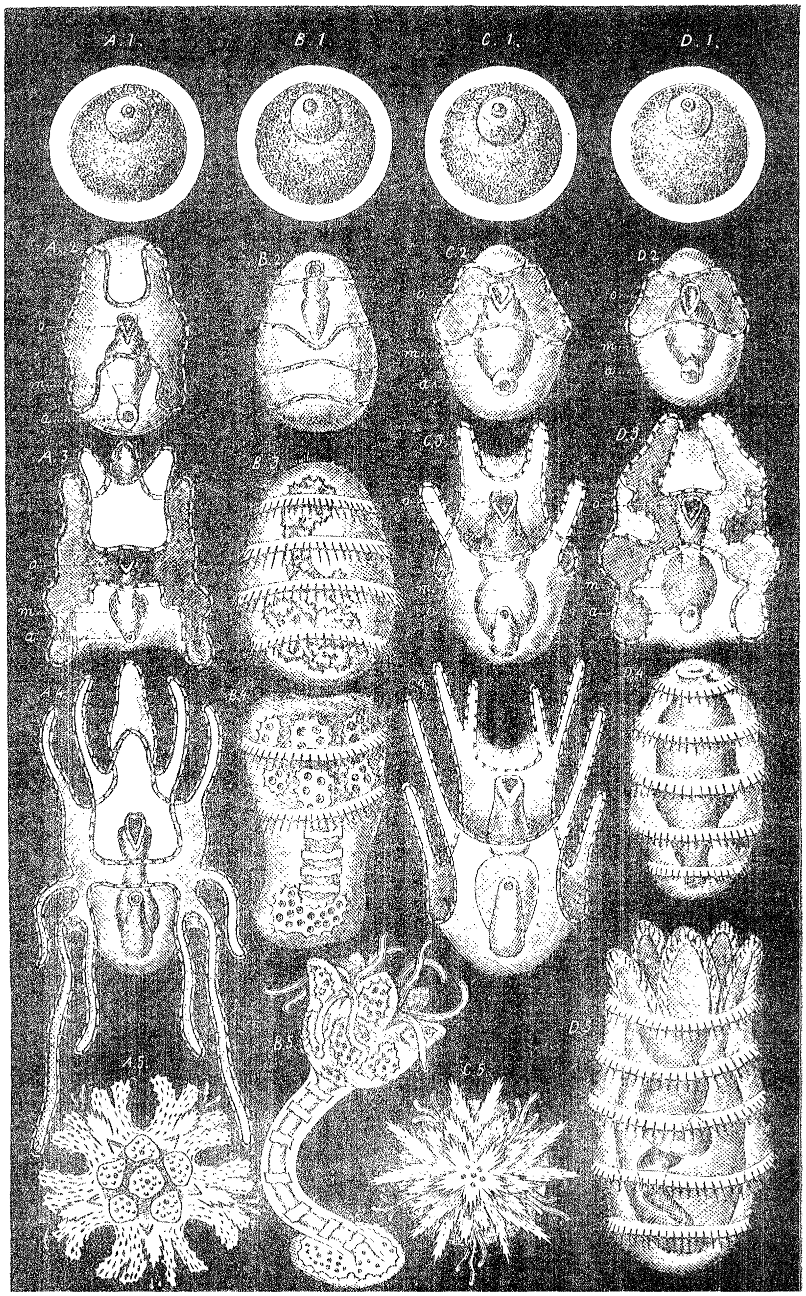
The tribe of Star-fishes or Prickly Skins (*Echinoderma* or *Estrellæ*) includes the Sea-stars, Sea-suns, Sea-buds, Sea-lilies, Sea-apples, Sea-urchins, and Sea-cucumbers. (Compare Plate IX.; also the systematic survey of the different classes on p. 226, and the pedigree on p. 227.) They form one of the most interesting divisions of the animal kingdom, and yet we know less about them than any other. They all live in the sea, in the economy of which they play an important part. Any one who has spent a couple of weeks at the sea-shore must have seen at least two of their forms, the Sea-stars and Sea-urchins. On account of their peculiar organization, the Echinoderma must be regarded as an entirely independent tribe of the animal kingdom, and more especially be classed entirely apart from the Cnidaria or Acalephæ, with which they were formerly erroneously classed as Radiated animals (Radiata).

All Echinoderma are characterized by the union of several very peculiar circumstances in the structure of their body, and herein differ widely from all other tribes of animals.

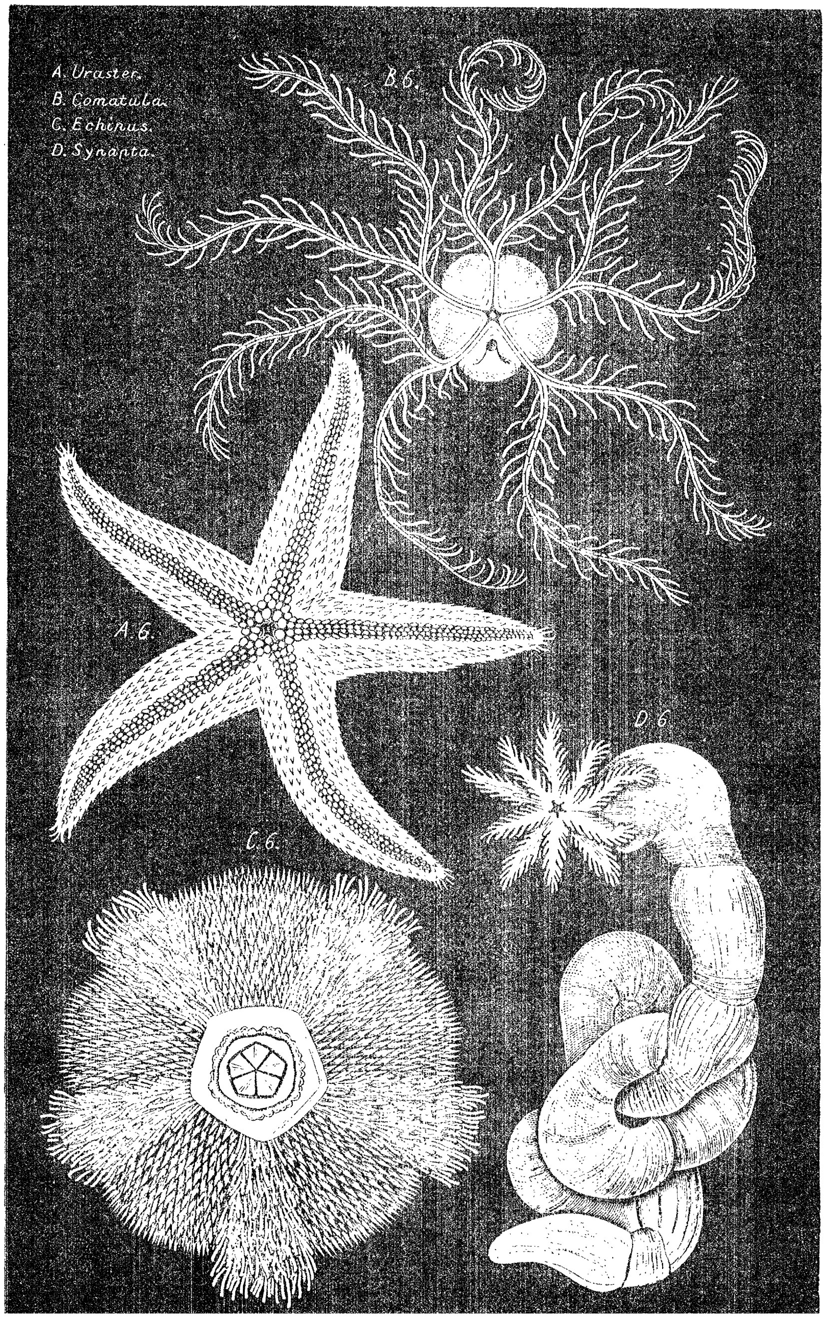
Among the chief of these morphological characteristics we consider the five-rayed, symmetrical fundamental form, the calcareous skeleton of the leathern skin, the five-rayed nerve-band of the nervous system, and, above all, the system of water canals or tubes. Even upon a superficial examination of the outer form, the Echinoderma are conspicuous by the *five-rayed symmetry of their fundamental form* (see Plate IX.). The body consists almost invariably of five radii or paramera, which stand out round the main axis of the body in the form of a star, and meet in that axis. It is only in a few species of Sea-stars that the number of these radii amount to more than five; but some are known with from six to nine, ten to twelve, or even from twenty to forty; in these cases the number of the radii is generally not permanent, but variable. The five paramera themselves possess a bilaterally symmetrical and articulated body, composed of two symmetrical halves or antimera, like a Ring-worm. Sometimes all five pieces are of equal formation, at other times they differ in such a manner that the whole five-rayed body itself appears bilateral, and composed of two antimera, with a longitudinal plain in the centre, halving it. In this central plain lies a non-paired paramer, while the four others are placed in pairs on both halves, on either side a front one and a back one. The internal construction of the body generally shows an indication of this bilateral symmetry; and as it is met with generally in their earliest youth, it must be regarded as a primæval inheritance.

The peculiar five-rayed skin-skeleton of the Echinoderma is produced by the leathern skin becoming calcified, by the deposit of delicate microscopic calcareous rods in the

STAR FISHES. FIRST GENERATION. WORM PERSON.



STAR FISHES. SECOND GENERATION. WORM STOCK.



tissue of the corium; generally these little rods connect themselves into latticed plates; and in many of the Echinoderma these become large plates of mail, which, standing together in a very characteristic position, form a firm case or house, like an external calcareous shell.

As characteristic, again, of the Echinoderma is the peculiar form of their central nervous system. In the same way as the Worms are distinguished by their simple primæval brain, the Molluscs by their double gullet-ring, the Articulata by the ventral nerve-cord, and the Vertebrata by their spinal cord, the Echinoderma have their peculiar nervous system—a gullet-ring, from the rim of which ventral cords radiate into every arm (as a rule, therefore, five). This star of nerve-tissue, like the ventral cord of the Articulata, runs along the ventral side of every segmented radius or paramer right to the end.

The Echinoderma are further distinguished from all other animals by their peculiar *ambulacral system*, a most remarkable apparatus for locomotion. This consists of a complicated system of canals or tubes, which are filled with water from without. The sea-water in these aqueducts is moved partly by the strokes of the cilia, partly by the contractions of the muscular walls of the tubes themselves, which resemble india-rubber bags. The water is pressed from the tubes into a number of little hollow feet, which thereby become greatly distended, and are then employed for walking and suction. Every little foot is connected with a little internal bladder. If the Echinoderm wants to creep, it presses the water out of the little bladder into the little feet. In early youth already, there develop round the mouth five arms, which are filled from the water

vascular ring of the mouth. The tentacles, the gills, and other organs are supplied by the ambulacral system.

All Echinoderma, further, possess a well-developed alimentary canal, a body-cavity, a system of blood-vessels, very highly developed muscles, separate sexes (rarely united), etc. In short, taken as a whole, they appear morphologically to be very highly organized animals, whereas physiologically, and especially as regards activity of soul, they stand at a very low stage. Their ontogeny is most remarkable; by some regarded as alternation of generation, by others as metamorphosis. It throws a curious light upon the phylogeny of this tribe. Within the individual classes it is pretty clear, for numerous admirably preserved fossils enlighten us on the historical development of the smaller and larger groups. But the primary relationships between the classes, and the question as to their common origin from an earlier ancestral form, is an extremely difficult, though certainly also an extremely interesting, problem of their phylogeny.

Numerous and varied attempts to solve this problem have been made during the last twenty years, and especially during the last decade; however, without any definite result. Two of these *hypotheses on the phylogeny of the Echinoderma* we shall now briefly describe, and contrast with each other, because they undertake to solve the problem from opposite points of view. The earlier one we shall briefly designate as the *Pentastrœa hypothesis*, the later one as the *Pentactœa hypothesis*. The former starts with the highly decentralized Sea-stars (Plate IX., Fig. *A*), and considers the highly centralized Sea-cucumbers (Fig. *D*) as the last stage of development; the latter hypothesis exactly

the reverse. Both hypotheses—like all the other attempts—agree in the supposition that the *Echinoderma are derived from Helminthes*, and indeed from bilaterally symmetrical worms with intestinal canal and body-cavity; the latter having originated out of a pair of intestinal pouches or cœlom-sacs. But how this origin is to be conceived, and what records of phylogeny are to be considered authoritative, are points upon which opinions differ widely.

The earlier or Pentastræa hypothesis was established by me in 1866, in my "General Morphology" (vol. ii., Table IV., pp. lxi.–lxxvii.). According to it, the class of *Sea-stars* (*Asterida*) would have to be regarded as the earliest and original group of the Echinoderma. This is confirmed, not only by numerous and important testimonies of their comparative anatomy and ontogeny, but more especially by the still inconstant and changing number of the radii or paramera met with in this class, whereas in all the other Echinoderma, without exception, the number is fixed at five. Every Sea-star consists of a central, small body-disc, all round the circumference of which are attached five or more long articulated arms. Each arm of the Sea-star essentially corresponds in its organization with an articulated worm of the class of Ring-worms or Annelids. I therefore considered the Sea-stars as a genuine stock or cormus of five or more articulated worms, which have arisen by the star-wise growth of a number of buds out of a central mother-worm. The connected members, thus grouped like the rays of a star, have inherited from the mother-worm the common opening of the mouth, and the common digestive cavity (the stomach) lying in the central

body-disc. The end by which they have grown together, and which fuses in the common central disc, probably corresponds to the posterior end of the original independent worms.

In exactly the same way several individuals of other tribes of animals are united so as to form a star-like cormus. This is the case in the *Botryllidæ*, compound Ascidians, belonging to the class of the Tunicata. Here also the posterior ends of the individual persons have grown together. and have formed a common outlet for discharges, a central cloaca; whereas at the anterior end each person still possesses its own mouth. In Sea-stars the original mouths have probably become closed in the course of the historical development of the cormus, or colony, whereas the cloaca has developed into a common mouth for the whole cormus.

Hence the Sea-stars would be compound stocks of worms which, by the radial formation of buds, have developed out of true articulated worms, or Annelids. This hypothesis is most strongly supported by the comparative anatomy, and by the ontogeny of articulated Sea-stars and of segmented worms. The many-jointed Ring-worms (Annelida)—which we class among the Articulata—in their inner structure are closely allied to the individual arms or radii of the Star-fishes, that is to the original single worms, which each arm represents. Each of the five worms of the Sea-stars is a chain composed of a great number of equi-formal members, or metamera, lying one behind the other, like every segmented Worm, and every Arthropod. As in the latter a central nervous cord, the ventral nerve-cord, runs along the central line of the ventral wall of each segment. On each metameron there is a pair of non-jointed feet, and besides

these, in most cases, one or more hard thorns or bristles similar to those of many Ring-worms. A detached arm of a Star-fish can lead an independent life. In many species of Sea-stars (Ophidiastes, Linckia, Brisingia, etc.) the detached arms can, by a radially directed growth of buds, reproduce the entire star, the central disc together with all the other arms. These are the so-called "comet-formations" of Sea-stars.

Important proofs of the truth of my Pentastræa hypothesis seem further furnished by the ontogeny or the individual development of the Echinoderma. The most remarkable facts of this ontogeny were first discovered in the year 1848 by the great zoologist, Johannes Müller, of Berlin. Some of its most important stages are represented on Plates VIII. and IX. (Compare their explanation in the Appendix.) Fig. *A* on Plate IX. shows us a common Sea-star (Uraster), Fig. *B*, a Sea-lily (Comatula), Fig. *C*, a Sea-urchin (Echinus), and Fig. *D*, a Sea-cucumber (Synapta). In spite of the extraordinary difference of form manifested by these four representatives of the different classes of Star-fishes, yet the beginning of their development is identical in all cases. Out of the egg (Plate VIII., Fig. *A* 1—*D* 1) a *Gastrula* is developed, and out of the latter an animal form, wholly different from the fully developed Star-fishes, but extremely like the ciliated larvæ of some worms. This peculiar animal form is called *Dipleurula* (Fig *A* 3—*D* 4). Some call it the "larva" of the Star-fishes, others call it the "nurse." It is very small, transparent, and swims about in the sea by means of a fringe of cilia, and possesses a simple intestine with mouth and anus. Both orifices lie in the central disc of the bilateral body, and so likewise does the

mesenterium. Out of the intestine, at the side, grow a pair of cœlom-pouches, the beginnings of a body-cavity. Accordingly, the Dipleurula is invariably composed of two symmetrical, equal halves, of *one* " pair of antimera." The fully grown Echinoderm, however, which is frequently more than a hundred times larger, and quite opaque—creeps at the bottom of the sea, and is always composed of at least five co-ordinate pieces (or *five* pairs of antimera). Plate VIII. shows the development of the "nurses," or "larvæ," of the four Echinoderms represented on Plate IX.

The fully developed Echinoderm arises by a very remarkable process of budding in the interior of the "nurse," of which it retains but one part of the body, more especially the stomach and body-cavity. The " nurse " or so-called " larva " of the Echinoderm must accordingly be regarded as a solitary worm, which by internal budding produces a second generation. The whole of this process, accordingly, is a genuine *alternation of generation* or metagenesis, not a " metamorphosis," as is generally stated. For it is only by actual *increase*, not by mere *change*, that *five* pairs of antimera can arise out of *one* pair of antimera, or out of a " paramer." A similar alternation of generation also occurs in many other worms, especially in some star-worms (Sipunculidæ) and cord-worms (Nemertinæ). Now if, bearing in mind the fundamental law of biogeny (vol. i. p. 356), we refer the ontogeny of Echinoderma to their phylogeny, we may assume that the earlier primary forms of the Star-fishes were bilateral worms with a body-cavity, that adapted themselves to an adherent mode of life, and formed five-rayed stocks by budding.

Besides the reasons mentioned, there are many other facts

(principally from the comparative anatomy of Echinoderma) which most distinctly prove the correctness of my Pentastræa hypothesis. I established this hypothesis in 1866, without having any idea that *fossil articulated worms* still existed, apparently answering to the hypothetical primary forms. Such have in the mean time, however, really been discovered. In a treatise "On the Equivalent of the North American Taconic Schist in Germany," Geinitz and Liebe, in 1867, have described a number of articulated Silurian worms, which completely confirm my suppositions. Numbers of these very remarkable worms are found in an excellent state of preservation in the Silurian slates of Würzbach, in the upper districts of Reusz. They are of the same structure as the articulated arm of a Star-fish, and evidently possessed a hard coat of mail, a much denser, more solid cutaneous skeleton than other worms in general. The number of body-segments, or metamera, is very considerable, so that the worms, although no more than a quarter or half an inch in breadth, attained a length of from two to three feet. The excellently preserved impressions, especially those of the Phyllodocites thuringiacus and Crossopodia Henrici, are strikingly like the arms of many Sea-stars (Colastra.) This primæval group of worms, which are most probably the ancestors of Sea-stars, I call Mailed worms (Phracthelminthes).

The phylogenetic system of the Echinoderma tribe, with its wealth of forms, would, in accordance with my Pentastræ hypothesis, first of all fall into three main divisions and six classes. And as the class of Sea-stars (*Asterida*) has most faithfully retained the original form of the stellate colony of worms, and further, as the inner centralization of

the other Star-fishes is for the most part wanting in these Asterida, they would have to be regarded as the common, earliest ancestral group of the whole tribe. The *Snake-stars* (*Ophiuræ*) resemble the Sea-stars, and are, upon the whole, still closely allied to them; and yet the central disc is already sharply marked off from the five long arms. In the Sea-stars every arm still possesses the complete organization of the worm, whereas in the Snake-stars this is no longer the case. However, even now the two classes are connected by transition-forms; both together form the main class of Star-fish with arms (*Anthosellæ* or *Asterozoa*).

As a second main class we take the Calyx Star-fish (*Pectostellæ* or *Pelmatozoa.*) They embrace three different classes: the Sea-lilies (*Crinoidea*, Plate IX., Fig. *B*), the Sea-buds (*Blastoidea*), and the Sea-apples (*Cystoidea*). The last two classes are primæval, and long since extinct; we know only their fossilized coat of mail from the archæolithic and palæolithic formations. The Sea-lilies also are for the most part extinct; however, there are still many of their epigones, especially in the deep sea. All three classes of Pectostellæ are characterized by the fact that they have given up the free locomotion of the other Star-fish, have become adherent, and developed a more or less long stalk. They have thus, in many respects, become very degenerated. Some Sea-lilies, however, again detach themselves subsequently from their stalk—thus, for instance, the Comatulæ (Fig. *B*, on Plates VIII. and IX.).

The third main class of the Echinoderms is formed by the Capsule Star-fish (*Thecostellæ* or *Echinozoa*): the two classes of the Sea-urchins and Sea-cucumbers. In this case the articulated arms are no longer independent parts, but

by the increased centralization of the stock have completely fused so as to form a common, inflated, central disc, which now looks like a simple box or capsule without arms, or a cylindrical pouch, like a worm. The original stock of individuals has thereby apparently degenerated to the form-value of a single person. In many respects the class of Sea-urchins (*Echinida*), with its numerous forms, stands next to the Sea-stars. It takes its name from the numerous and frequently very large bristles which cover the hard shell which is itself artistically built up of calcareous plates (Fig. *C*, Plates VIII. and IX.). The fundamental form of the shell itself is a pentagonal pyramid. The various sub-classes of the Sea-urchins furnish striking illustrations of the laws of progress and of differentiation by their historical succession, just as do the several fossil groups of Sea-lilies and Sea-stars. Although the history of the above classes of Star-fishes is very accurately narrated to us by the numerous and well-preserved fossils, we know next to nothing of the historical development of the last class, the Sea-cucumbers (Holothuriæ). These curious sausage-shaped Star-fish manifest externally a deceptive similarity to worms (Fig. *D*, Plates VIII. and IX.). The skeletal structure of their skin is very imperfect, and hence no distinct remains of their elongated, cylindrical, worm-like body could be preserved in a fossil state. My Pentastræa hypothesis infers, from the comparative anatomy and the ontogeny of the Holothuriæ, that the class probably originated from a division of Sea-urchins, by a softening and degeneration of the cutaneous skeleton. They would accordingly have to be regarded as the latest class of the tribe of Star-fishes, and the one that has changed most.

Similar views have again recently been entertained by Otto Hamann, in his careful investigations on the histology of the Echinoderms.

For twenty years my Pentastræa hypothesis remained the only comprehensive attempt that was made to establish the history of the pedigree of the Echinoderma monophyletically, and to explain the primary relationships of the classes by an equal consideration of all the three records of creation—comparative anatomy, ontogeny, and palæontology. During that time all three archives received extremely valuable contributions through the careful investigations of a number of scientific men; and a perfectly new light was thrown upon the difficult problems of phylogeny by a host of surprising discoveries. These gradually led to an entirely different conception of the organization of the Echinoderms, and, during these latter years, to various attempts to explain them phylogenetically. The most comprehensive of these attempts, and the one which, considering the present state of our knowledge of the subject, seems probably to approach the truth most nearly, was made by Richard Semon in his ingenious and suggestive work on "The Development of the Synapta Digitata, and the History of the Development of the Echinoderma" (Jena, 1888). The brothers Sarasin arrived at precisely similar results in their beautiful treatise, "On the Anatomy of the Echinothuriæ, and the Phylogeny of the Echinoderma" (Wiesbaden, 1888).

Semon's *Pentactæa hypothesis* agrees with my Pentastræa hypothesis in the supposition that all Echinoderma must be monophyletically derived from one common ancestral form, and that this ancestral form was a dipleurous, worm-like

animal, with a bilaterally-symmetrical fundamental form, a simple intestinal canal, and a pair of cœlom-pouches. But Semon assumes that the different classes of Star-fishes have developed out of this common ancestral form (*Pentactœa*) *divergently,* independently of one another. In the ontogeny of all Echinoderms an important larval stage is met with, the *Pentactula,* which, according to the biogenetic law, repeats the inherited formation of the hypothetical *Pentactœa.* The different larval forms (represented on Plate VIII.) *converge* towards this bilateral Pentactula, whereas the subsequent stages of development of the different class diverge from it. The median position of the intestine, which is attached by a dorsal mesenterium to the wall of the body, as well as the two cœlom-pouches that grow out of it, are undoubted testimonies of the bilateral symmetry of the Pentactula-larva, and of their descent from old Helminthes.

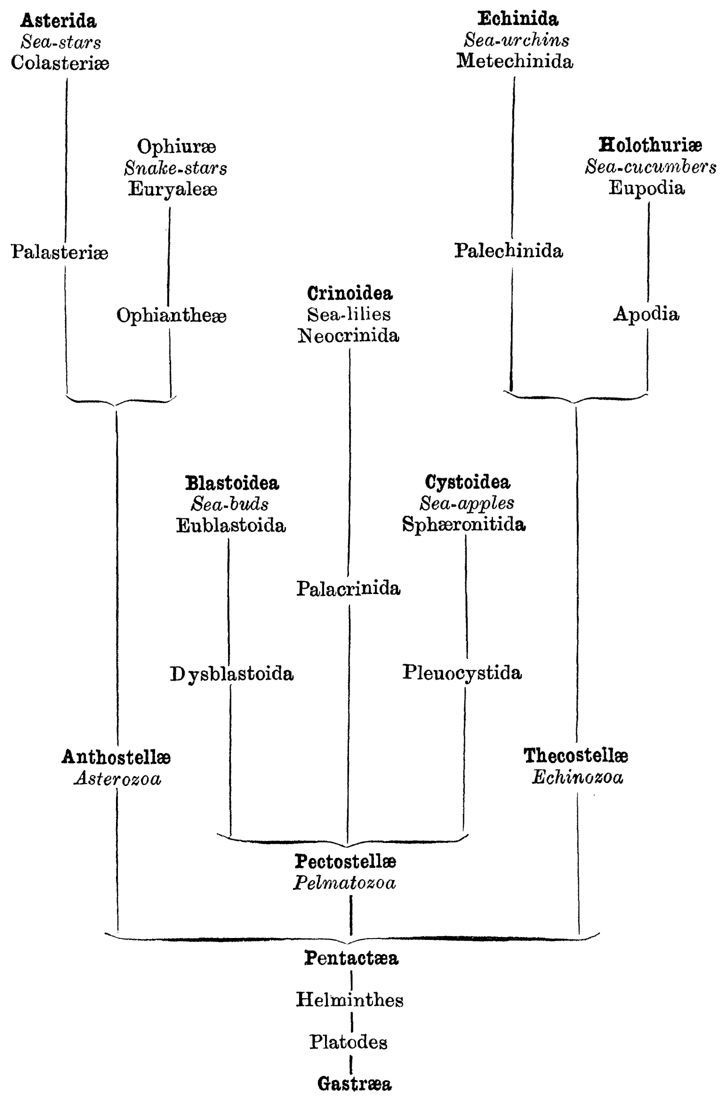
On the other hand, however, a wreath of five primary tentacles that develop round the mouth, and the five water-ducts that run into it (starting from a gullet-ring), point to the five-rayed organization which, in its further development, becomes so significant for the tribe of Star-fish (compare Plate XVIII., Fig. 4, 5). The typical fundamental form of the Pentactula is, accordingly, the pentamphipleurous, or the five-rayed symmetrical fundamental form.

The cause of the fundamental form of five rays must be looked for in their adaptation to an adherent mode of life. The older, freely swimming ancestral form (Helminthes), which still recurs in the Dipleurula (Plate VIII.) by inheritance, subsequently adhered to the bottom of the sea.

SYSTEMATIC SURVEY

Of the Classes and Orders of the Star-fishes (Echinoderma).

Main Classes of Star-fishes.	*Classes of the Star-fishes.*	*Orders of the Star-fishes.*	*Generic Name as Example.*
I. First Main Class **Thecostellæ** **(Echinozoa)** Capsule Star-fishes	I. Sea-cucumbers **Holothuriæ** (Scytoderma)	1. Sea-cucumbers without aquatic feet **Apodia**	Synapta Molpadia
		2. Sea-cucumbers with aquatic feet **Eupoida**	Pentacta Elpidia
	II. Sea-urchins **Echinida**	3. Older Sea-urchins **Palechinida**	Melonites Protechinus
		4. More recent Sea-urchins **Metachinida**	Sphærechinus Spatangus
II. Second Main Class **Pectostellæ** **(Pelmatozoa)** Calyx Star-fishes	III. Sea-apples **Cystoidea** (fossil only)	5. Bilateral Cystoidea **Pleurocystida**	Trochocystites Pleurocystites
		6. Spherical Cystoidea **Sphæronitida**	Sphæronites Echinosphærites
	IV. Sea-buds **Blastoidea** (fossil only)	7. Bilateral Blastoidea **Dysblastoida**	Codonaster Eleutherocrinus
		8. Regular Blastoidea **Eublastoida**	Pentremites Elæacrinus
	V. Sea-lilies **Crinoidea**	9. Older Sea-lilies **Palacrinida**	Rhodocrinus Cyathocrinus
		10. More recent Sea-lilies **Neocrinida**	Rhizocrinus Comatula
III. Third Main Class **Anthostellæ** **(Asterozoa)** Flower Star-fishes	VI. Snake-stars **Ophiuræ**	11. Simple Snake-stars **Ophiantheæ**	Ophiolepis Ophioderma
		12. Branching Snake-stars **Euryaleæ**	Astroporpa Astrophytum
	VII. Sea-stars **Asterida**	13. Older Sea-stars **Palasteriæ**	Palæaster Lepidaster
		14. More recent Sea-stars **Colasteriæ**	Astropecter Ophidiaster


Asterida
Sea-stars
Colasteriæ
Ophiuræ
Snake-stars
Euryaleæ
Palasteriæ
Ophiantheæ
Echinida
Sea-urchins
Metechinida
Holothuriæ
Sea-cucumbers
Eupodia
Palechinida
Apodia
Crinoidea
Sea-lilies
Neocrinida
Blastoidea
Sea-buds
Eublastoida
Cystoidea
Sea-apples
Sphæronitida
Palacrinida
Dysblastoida
Pleuocystida
Anthostellæ
Asterozoa
Thecostellæ
Echinozoa
Pectostellæ
Pelmatozoa
Pentactæa
Helminthes
Platodes
Gastræa

It changed itself into the Pentactæa, and probably adhered to the bottom of the sea by a stalk at the end opposite the mouth-orifice. This original stalk has been transmitted to most Pectostellæ, whereas the Anthostellæ and Thecostellæ detached themselves from the stalk, and reacquired the lost power of free locomotion. Other worms (*e.g. Loxosoma* among the Bryozoa) develop a wreath of radial tentacles round the mouth, while the opposite end of the body is attached to the bottom of the sea by a stalk.

The Synaptæ, or the simplest Holothuriæ—with the ontogeny of which Semon started—are, according to him, the original and oldest of all the living groups of Star-fishes, and have retained most faithfully the more important features of the Pentactæa organization by inheritance. According to my Pentastræa theory, on the other hand, they would have to be regarded as the most recent branch of the tribe having become disfigured by degeneration, and very much changed by adaptation. The Sea-stars, and more especially the "comet forms" (with extreme independence of the five arms), which, in accordance with my hypothesis, represented the oldest and original form of the tribe, would (according to the Pentactæa hypothesis), on the contrary, have to be regarded as the most recent branch, having been greatly changed by decentralization.

An examination of these two hypotheses, and various other attempts that have recently been made with a view to explaining the pedigree of the Echinoderma, cannot unfortunately be undertaken here, because the subject is one that demands a special knowledge of the extremely complicated circumstances in the comparative anatomy and ontogeny of this wonderful tribe of animals. But the

subject is not only most interesting in itself, but also very instructive for all the general aims and objects of phylogenetic zoology. We can infer from this what great value the phylogenetic method possesses for solving difficult and complicated morphological questions. And even though none of the various hypotheses on the origin of the Echinoderma may be quite correct, still they have thrown considerable light upon the great obscurity which has hitherto enveloped our knowledge of this very peculiar tribe of animals. Numerous points of view have been found, giving an insight into the affinities between the different classes, and new phylogenetic relations between them.

It would be unfair to expect that phylogeny—a science that was unknown twenty-five years ago—should already be showing mature fruit on all sides. But, together with numerous already matured products, it shows us everywhere on the tree of knowledge blossoming flowers and promising buds—phylogenetic problems, the gradual solution of which offers the most interesting work, and the most hopeful results to the thinking and inquiring mind of man.

CHAPTER XXIII.

PEDIGREE AND HISTORY OF THE ARTICULATED ANIMALS.

The Four Classes of Articulated Animals of Cuvier.—Subsequent Separation of the Annelids from the Arthropods.—The Three Main Classes of the Annelids, Crustacea, and Tracheata.—Their Common Characteristics.—Their Derivation from a Common Form.—Primary Group of the Annelids, or Ringed Worms (Leeches and Bristled Worms).—Main Class of the Crustacea.—Its Division into Two Diverging Classes: Crabs (Caridonia) and Shield Crabs (Aspidonia).—Derivation of the Caridonia from Archicaridæ.—Nauplius.—Relationship between the Aspidonia and the Arachnida.—Main Class of the Tracheata, Air-breathing Tracheate Insects.—Their Four Classes: Protracheata (Peripatus), Centipedes (Myriapoda), Spiders (Arachnida), and Insects.—Organization and Pedigree of the Insects.—Their Division into Four Legions according to the Form of Mouth.—Older Wingless Insects (Thysanura).—More Recent Winged Insects (Pterygonia).—Insects with biting, licking, stinging, and sipping Form of Mouth.—History and Pedigree of the Insects.

When we examine and compare the historical development of the various animal tribes from a higher point of view, we observe striking differences in the time and place of their development. Even the number of the smaller or larger groups of forms—into which every tribe diverges—is very different, not only as seen in regard to the individual periods of the organic history of the earth, but also taken as a whole. For the struggle for existence at all times and in every place determines the manifold circum-

stances of the development; hence it evolves the several tribes in the most various ways. If we were to judge each tribe according to the number of its species, and to take as our standard the variety of the manifold forms which have arisen by natural selection, one of the tribes would take undoubted precedence over all the others; this is the most highly developed tribe among the Invertebrata, the phylum of *Articulated Animals* (*Articulata*).

This name Cuvier, in 1817, gave to the four classes of invertebrate animals, which are all distinguished by the striking *outward articulation* of their body, and by a characteristic nervous system, viz. a ventral nerve-cord with gullet-ring. These four classes were: the Ringed Worms (*Annelida*), the Crabs (*Crustacea*), the Spiders (*Arachnida*), and the Insects (*Insecta*). The last three classes possess articulated legs, and the rings of the body are very unequal. On the other hand, the articulation of the Ringed Worms is more equal, and they have either no legs at all, or legs that are not articulated. For this reason they were subsequently generally classed among the footless Worms or Worm-like animals; and the other articulated animals were classed under the name of Joint-footed (*Arthropoda*) as a special type. Recent zoologists, following Brönn's example, distinguish two main groups in this type, viz. (1) the Crabs (*Crustacea*), which breathe water through gills; and (2) the air-breathing animals (*Tracheata*), which breathe through wind-pipes, or tracheæ. The latter are divided into three classes—the Centipedes (*Myriapoda*), Spiders (*Arachnida*), and genuine six-legged Insects (*Insecta*).

This more recent and, meanwhile, customary method of dividing the Arthropoda has, however, lately again under-

gone an essential alteration, owing to our fuller knowledge of the history of their development. The gap between the Crustacea and the Tracheata has been made wider still, whereas the latter are again placed much nearer the Annelids. Of decisive importance in this matter, was the discovery of the finer construction and development of a curious, primæval form of articulated animal, which had hitherto been classed among the Ringed Worms. This is an interesting creature like a centipede, named Peripatus, which lives in the damp earth of tropical regions. Moseley, one of the able zoologists of the renowned *Challenger* Expedition, has shown that the Peripatus possesses actual wind-pipes or tracheæ, and forms, accordingly, a direct connection between Ringed Worms and Tracheata.

In consequence of this important discovery, and after duly considering their organization and development as a whole, I now—with a wholly unbiassed mind—consider the more correct plan is to do away with the tribe of type of Arthropoda (those with articulated feet) and to return to Cuvier's old idea of Articulated Animals (Articulata). As regards the more recent and important advances in our knowledge of the structure of their body and of their development, I distinguish among the Articulata three main classes: (1) Annelids, (2) Crustacea, and (3) Tracheata. The Ringed Animals (*Annelida*) I divide into two classes—Leeches (*Hirudinea*) and Bristled Worms (*Chætopoda*), the former without feet, the latter with non-articulated feet. The Encrusted Animals (*Crustacea*) I likewise divide into two classes—the Crabs (*Cardonia*) and the Shield-animals (*Aspidonia*), the former with two pairs of feelers, the latter with one pair. The *Tracheata*, or air-breathing animals,

lastly, must be divided into four classes. The first class is formed by the primæval air-breathers (*Protracheata*), of which the only survivor now is the Peripatus, with numerous non-articulated pairs of legs; as the second class, we have the Centipedes (*Myriapoda*), with numerous articulated pairs of legs; as the third class, the Spiders (*Arachnida*), with four pairs of legs; and, lastly, as the fourth class, the genuine Insects (*Insecta*), with six pairs of legs.

All of these Articulata agree in this, that their body originally consists of a large number (at least eight to ten, often twenty to fifty, and more) of *parts* lying in a longitudinal axis one behind the other, which we term body-segments, somites, rings, or metamera. Externally this articulation is generally very distinct, inasmuch as the skin is surrounded by a firm covering of chitin, and this is drawn in between every two segments ring-wise. The articulation is, however, even more strongly expressed in the repetition of the internal organs, inasmuch as each segment or metamer possesses a part of the vascular system, of the muscular system, and of the nervous system, etc. And highly characteristic, in this respect, above all else is the structure of the central nervous system which invariably exhibits the so-called ventral nerve-cord with the gullet-ring. In each segment or metamer there is originally a pair of ganglia, and all these nerve-knots are united by longitudinal threads into a long chain, which runs along the ventral side under the intestine. The front knot of this chain, the "lower gullet-knot," lies in the head, and is connected by a string encircling the gullet (the gullet-ring) with the "upper gullet-knot," the upper half of the "primary brain."

The three main classes of the Articulata can be pretty sharply distinguished by various characteristics. The Annelids, for instance, are distinguished by their excretory organs or nephridia; these are long, twisted renal ducts, which are repeated in pairs in each metamer. The Tracheata, or air-breathers, on the other hand, are sharply defined by their curious air-tubes or tracheæ, which are not met with in any other class of animals. The Crustacea possess neither the metameric nephridia of the Ringed Worms, nor the tracheæ of the Tracheata; their chitin-covering is generally very thick and hard, containing lime, and like a crust (see Plate XVIII., Fig. 7–11).

Now, although the three main classes of the Articulata can be pretty easily and definitely distinguished by the above and other characteristics, still they appear, on the other hand, so closely allied that we are obliged to unite them into the *one tribe* of the Articulata. This animal tribe undoubtedly has its root in the tribe of Worms, or Helminthes. On the one side, the Annelids appear by several intermediate forms to be connected with the Round-worms (Nematoda), and perhaps also with the Cord-worms (Nemertina). On the other side, the youthful forms of many Annelids—more especially the so-called "Wheeled larvæ" (Trochophora)—stand very close to the small Wheel-animalcules (Rotatoria) in their organization. And among other Helminthes, also, there are interesting forms which approach the organization of the Annelids. The two classes of Arthropoda, the *Crustacea* and *Tracheata*, have most probably developed out of older Annelids as two diverging main groups, independently of each other. But whether these two main classes are derived from

one and the same group of Annelids, or whether they are descended from two or three different groups of Annelids, cannot, meanwhile, be safely determined. An origin from a single source cannot with certainty be maintained of the several classes distinguished among the three main classes of the Articulata. We may, however, meanwhile regard all Tracheata as descendants of *one* common primary form, also all Crabs, and all Annelids. How their phylogenetic connection may at present be imagined, is shown by the hypothetical pedigree on p. 237.

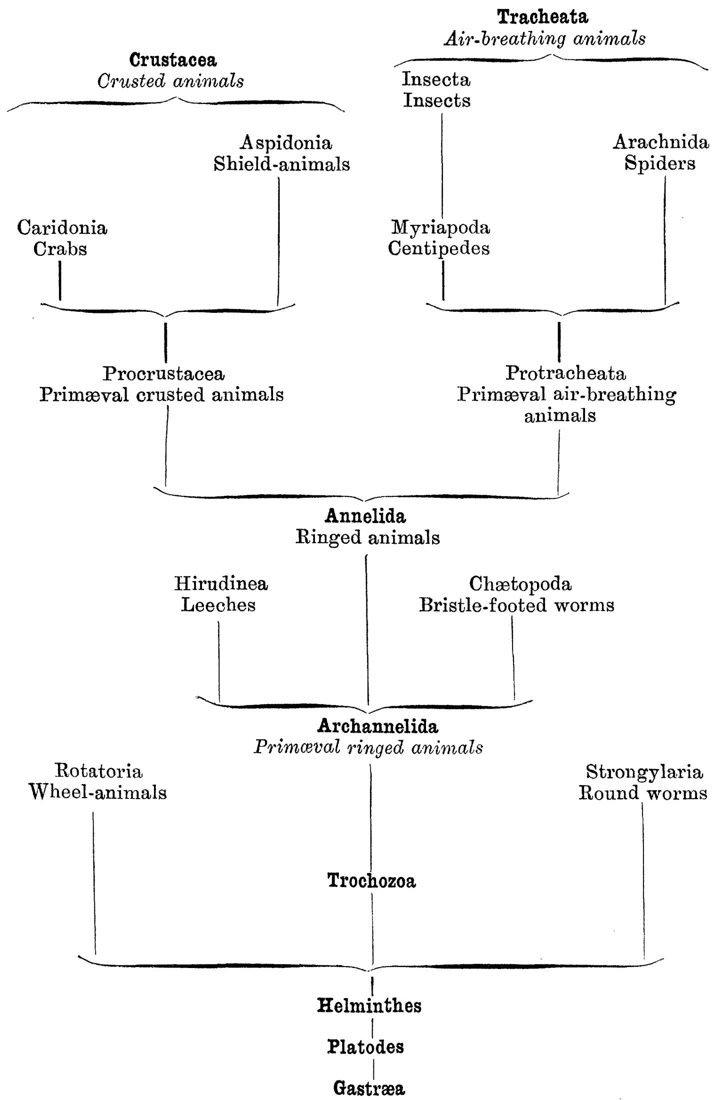
The first main class of the Articulata is formed by the Ringed Animals (*Annelida*), also frequently called Ringed Worms (*Annulata*). Their organization is in general simpler and more imperfect than that of the Crustacea and Tracheata. More especially the parts or segments of their body are generally very irregularly developed (homonomous); and their legs are never as distinctly articulated as in the case of the other two classes of Arthropods. The chitin-covering of their body is generally delicate and thin, often merely a fine cuticle. Specially characteristic, further, are the numerous renal tubes or nephridia, of which a pair exists in every segment or metamer. These "segmental organs" are not met with in the Crustacea or in the Tracheata; in other respects also these latter classes appear to be "higher articulated animals," although the characteristic type of the structure of the body remains the same in all three main classes or cladomes.

The great majority of Annelida live in the sea, a small number inhabit fresh waters (*e.g.* Leeches), and a few are found in the earth (*e.g.* Earth-worms). The main class with

SYSTEMATIC SURVEY

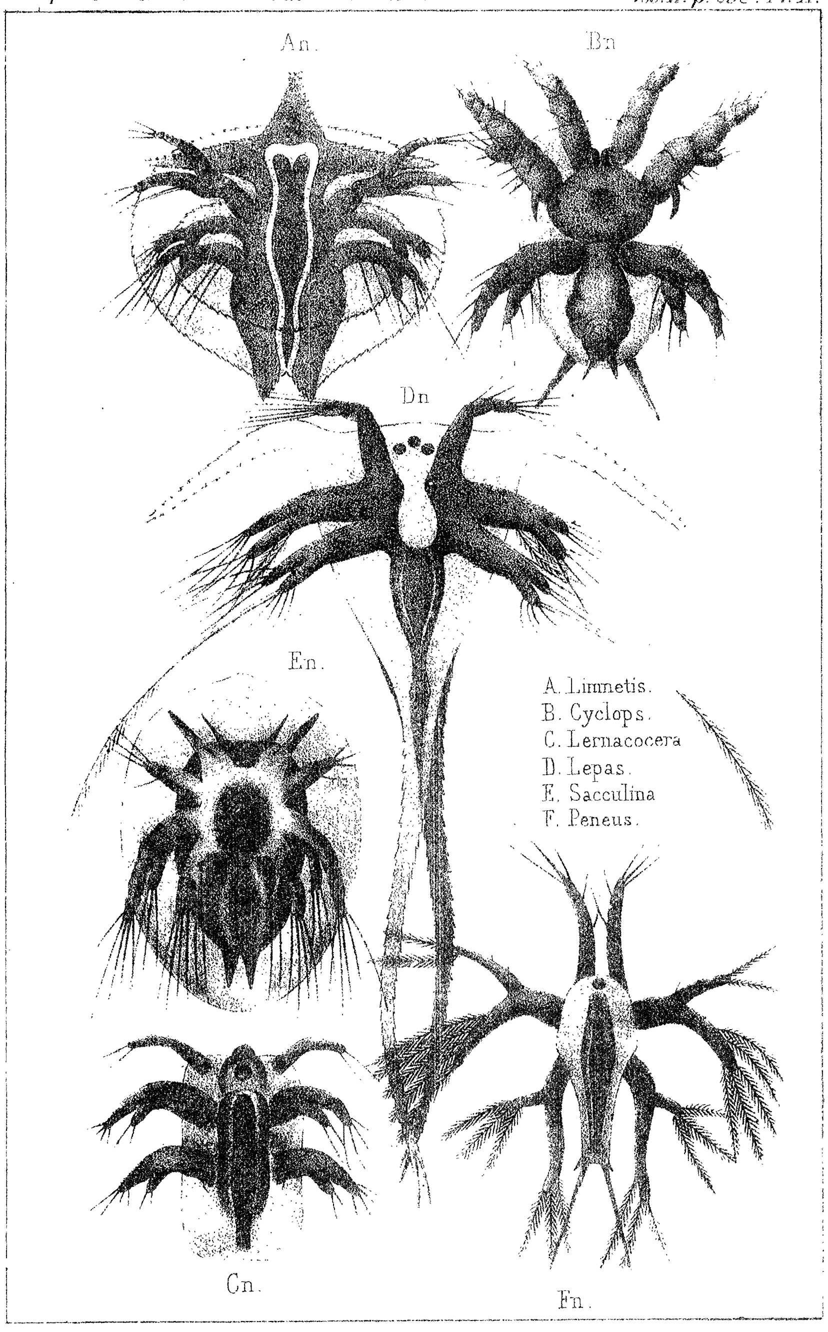
Of the Classes and Orders of the Articulata (Articulated Animals.)

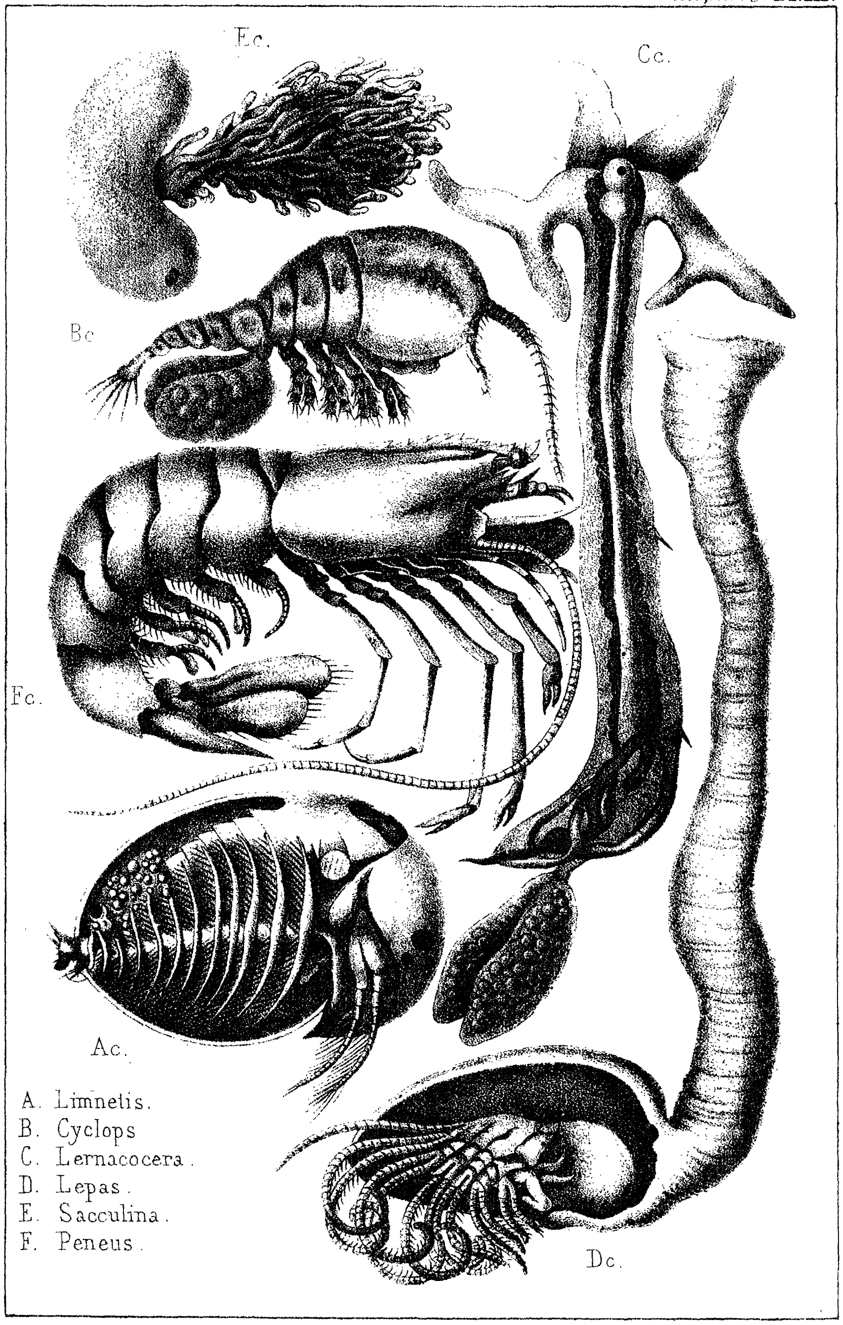
Main Classes: Cladome of the Articulata.	*Character of the Classes.*	*Classes of the Articulata.*	*Orders of the Articulata.*
I. **Ringed Animals** *Annelida* With segmental nephridia (without air-tubes or trachea)	1. No legs. In place of them suckers	1. Leeches. *Hirudinea.*	1. Rhynchobdellea. 2. Gnathobdellea.
	2. Numerous non-articulated pairs of legs or bristles	2. Bristle-footed worms. *Chætopoda.*	1. Oligochæta. 2. Polychæta.
II. **Encrusted Animals** *Crustacea* Without segmental nephridia (without air-tubes or trachea)	3. Nauplius-germ. Two pairs of feelers	3. Crabs. *Cardionia.*	1. Branchiopoda. 2. Copepoda. 3. Cirripeda. 4. Leptostraca. 5. Edriophthalma. 6. Podophthalma.
	4. No Nauplius-germ. One pair of feelers	4. Shield-animals. *Aspidonia.*	1. Trilobita. 2. Merostoma. 3. Xiphosura.
III. **Animals with Air-tubes** *Tracheata* Mostly without segmental nephridia (with air-tubes or tracheæ)	5. Numerous non-articulated pairs of legs	5. Primæval air-breathers. *Protracheata.*	1. Peripatida.
	6. Numerous articulated pairs of legs	6. Centipedes. *Myriapoda.*	1. Chilopoda. 2. Diplopoda.
	7. Four articulated pairs of legs	7. Spiders. *Arachnida.*	1. Scorparia. 2. Araneæ. 3. Acaria.
	8. Three articulated pairs of legs (and mostly two pairs of wings)	8. Insects. *Insecta.*	1. Thysanura. 2. Archiptera. 3. Neuroptera. 4. Strepsiptera. 5. Orthoptera. 6. Coleoptera. 7. Hymenoptera. 8. Hemiptera. 9. Diptera. 10. Lepidoptera.


Tracheata
Air-breathing animals
Crustacea
Crusted animals
Insecta
Insects
Aspidonia
Shield-animals
Arachnida
Spiders
Caridonia
Crabs
Myriapoda
Centipedes
Procrustacea
Primæval crusted animals
Protracheata
Primæval air-breathing animals
Annelida
Ringed animals
Hirudinea
Leeches
Chætopoda
Bristle-footed worms
Archannelida
Primæval ringed animals
Rotatoria
Wheel-animals
Strongylaria
Round worms
Trochozoa
Helminthes
Platodes
Gastræa

its wealth of forms falls into two distinct sub-classes, the Leeches and the Bristle-footed worms. The Leeches (*Hirudinea*), which include the leech used in medicine and many other parasites, possess no legs; in place of these, they have suckers by which they attach themselves for sucking. The Bristle-footed worms (*Chætopoda*), which for the most part live in the sea, have generally on each segment of their body one or two pairs of short non-articulated legs, armed with bundles of bristles. Other Chætopoda, as, for instance, the earth-worms and the fresh-water worms, have merely bundles of bristles in the skin, in place of legs. Many Annelida live enclosed in horny or calcareous tubes (*Tubicolæ*), and fossils of these have been found. Otherwise petrifactions of them are rare and unimportant, on account of the very delicate and soft nature of their body. A curious exception is formed by the well-preserved impressions of the Silurian Mailed worms (*Phracthelminthes*, see above, p. 221).

The large main class of the Encrusted Animals (*Crustacea*) has its name from the hard, crust-like skin-covering, a firm, often a calciferous, chitin-coat of mail. Most Crustacea live in the sea, a smaller number in fresh water, and but few on land. We divide them into two classes—the Crabs, or *Caridonia*, and the Shield-animals, or *Aspidonia*. The latter are represented in our day only by a single living genus, the great *Limulus*, or King-Crab. But the class includes a quantity of extinct forms—the huge Gigantostraca or Eurypterus, as well as the primordial group of the Trilobita or Palæades. All living Crustacea, with the single exception of the Limulus, belong to the rich class of Caridonia, or Crustacea in a narrower sense. Owing to the enormous


An.
Bn.
Dn.
En.
A. Limnetis.
B. Cyclops.
C. Lernacocera.
D. Lepas.
E. Sacculina.
F. Peneus.
Cn.
Fn.


Ec.
Cc.
Bc
Fc.
Ac.
Dc.
A. Limnetis.
B. Cyclops.
C. Lernacocera.
D. Lepas.
E. Sacculina.
F. Peneus.

mass of the individuals of this class which inhabit all our fresh and salt waters, they play an extremely important part in the economy of nature, similar to that played by the Insects on land. The Crustacea breathe through gills, never through wind-pipes like the Tracheata; but, like the latter, they possess articulated legs, and in this both of these classes differ from the Annelids. The nephridia of the Annelids have either quite disappeared in the Crustacea or have changed into other organs.

The class of true Crabs (*Caridonia*) is represented in our fresh waters by the well-known cray-fish, by numerous forms of louse-crabs and flea-crabs, as well as by numerous little Gill-footed Crabs (*Branchiopoda*). The latter (Daphnia, Cypris, etc.) inhabit our fresh waters in immense quantities, and are very important as scavengers and as forming the main food of many fish (*e.g.* the trout). But their wealth of forms and their œcological importance is far surpassed by the marine crabs, of which at least nineteen orders and over a hundred families can be distinguished. The ontogeny or individual development of these animals is exceedingly interesting, and distinctly reveals to us—as in the case of the Vertebrates—the essential features of the history of their tribe. Fritz Müller, in his admirable work already quoted, "For Darwin," has explained this remarkable series of facts in a very able manner.

The common embryonic form of all Crabs, which in most cases even now is the first to develop out of the egg, is originally one and the same, the so-called *Nauplius* (Plate X.). This remarkable primæval crab is a very simple form of articulated animal, the body of which, in general, has the form of a roundish, oval, or pear-shaped

disc, and has on its ventral side only three pairs of legs. The first of these is uncloven, the two subsequent pairs are forked. These three typical pairs of legs prove the Nauplius body to be composed of three segments or bodily parts. The body-cavity contains a simple intestinal tube, with mouth and anus. In front, above the mouth, lies a simple single eye. Although the different orders of the Crab-class differ very widely from one another in the structure of their body and its appendages, yet the youthful Nauplius-form always remains essentially the same. In order to be convinced of this, let the reader attentively examine Plates X. and XI., a more detailed explanation of which is given in the Appendix. On Plate XI. we see the fully developed representatives of six different orders of Crabs—a Leaf-footed Crab (Limnetis, Fig. *A c*); a Stalked Crab (Lepas, Fig. *D c*); a Root Crab (Sacculina, Fig. *E c*); a Boatman Crab (Cyclops, Fig. *B c*); a Fish Louse (Lernæocera, Fig. *C c*); and, lastly, a highly developed Shrimp (Peneus, Fig. *F c*). These six crabs vary very much, as we see, in the general form of body, in the number and formation of the legs, etc. When, however, we look at the earliest stages, or "nauplii," of these six different classes, after they have crept out of the egg—those marked with corresponding letters on Plate X. (Fig. *A n*—*F n*)—we shall be surprised to find how much they agree. The different forms of nauplius of these six orders differ no more from one another than would six different "good species" of one genus. Consequently, we may with assurance infer a common derivation of all those orders from a common Primæval Crab, allied to the Annelida, the larval form of which was very similar to the Nauplius of the present

day. This very important and long since extinct primary group we shall call *Archicarida*, or "Primæval Crabs."

When Fritz Müller (Desterro), in his excellent work "Für Darwin," had pointed out the general distribution of the Nauplius larva in all Crabs, and its great importance as a proof of the monophyletic descent of this rich class of animals, naturalists were inclined to recognize in the Nauplius itself (Plate X.) the original image (faithfully retained by inheritance) of the common primary form. I myself, like most other zoologists, in this sense derived all the different Caridonia from a common form like the Nauplius, a very ancient *Naupliad.* However, this hypothesis, and the application of the biogenetic law which supported it, required a certain limitation, as has recently been pointed out by Arnold Lang (the first "Professor of Phylogeny") in his admirable "Manual on Comparative Anatomy" (Jena, 1889, p. 421). The primordial (Cambrian) long since extinct primary form of Crabs—our "primæval Crab or Archicaris"—we have to imagine as a many-jointed Annelid, with numerous pairs of legs, with ventral nerve-cord and gullet-ring; in fact, an intermediate form between Polychæta and Phyllopoda. The pure Nauplius, in its original and simplest form, is the characteristic larva of this primæval Crab, and hence stands in the same relation to the Caridonia as the Wheel-larva (*Trochophora*) does to the Annelids. The Nauplius itself is derived from a Trochophora. Of course it must, on the other hand, be remembered that these simple larvæ themselves are of great phylogenetic importance, and that they have received their typical construction of body from an older group of non-articulated Helminthes.

The pedigree on p. 245 will show how we may at present

approximately conceive of the derivation of the different orders of Crabs, enumerated on p. 244, from the common primary group of Primæval Crabs (Archicarida). Out of the original Archicaris-form—which existed as an independent genus—there developed, as diverging branches in different directions, three legions of Lower Crabs or *Entomostraca*, the Gill-footed Crabs (*Branchiopoda*), the Oar-footed Crabs (*Copepoda*), and the Barnacle Crabs (*Cirripeda*). But also the three legions of the Higher Crabs or *Malacostraca*, the Primæval Mailed Crabs (*Leptostraca*), the sessile-eyed Mailed Crabs (*Edriophthalma*), and the stalk-eyed Mailed Crabs (*Podophthalma*), originated out of the common *Archicaris*. The primæval extinct Palæocarida of the Cambrian and Silurian systems (*Ceratocaris*) belonged, probably, to the primary forms of the Malacostraca. The *Nebalia* is still a direct form of transition from the Phyllopods to the Schizopods, and represents a remnant of the common primary group of the stalk-eyed and sessile-eyed Mailed Crabs. However, at this stage the larval form of the Nauplius in the first place changed into a different form of larva, the so-called Zoëa, which is of great phylogenetic importance.

The order most closely related to the primary group of the Leptostraca (Nebalia) is that of the Schizopoda, those with cloven feet (*Mysis*, etc.); for they are at present still directly allied through the Nebalia to the Phyllopoda, those with foliaceous feet. But of all living crabs the Phyllopods are the most closely related to the original primary form of the Nauplius. Out of the Schizopoda, the stalk-eyed and sessile-eyed Mailed Crabs, or Malacostraca, developed as two diverging branches in different directions; the former are still allied to Schizopoda by the Cumacea (Cuma) and the

Shrimps (Peneus), the latter by the Nipper-slaters (Anisopoda, Tanais). Among those with stalked eyes is the river-crab (cray-fish) and the other long-tailed crabs or Macrura, out of which—only at a later date in the Chalk period—the short-tailed crabs or Brachyura developed by degeneration of the tail. The sessile-eyed crabs divide into the two branches of flea-crabs (Amphipoda) and the louse-crabs (Isopoda), among which latter are our common rock-slaters and wood-lice.

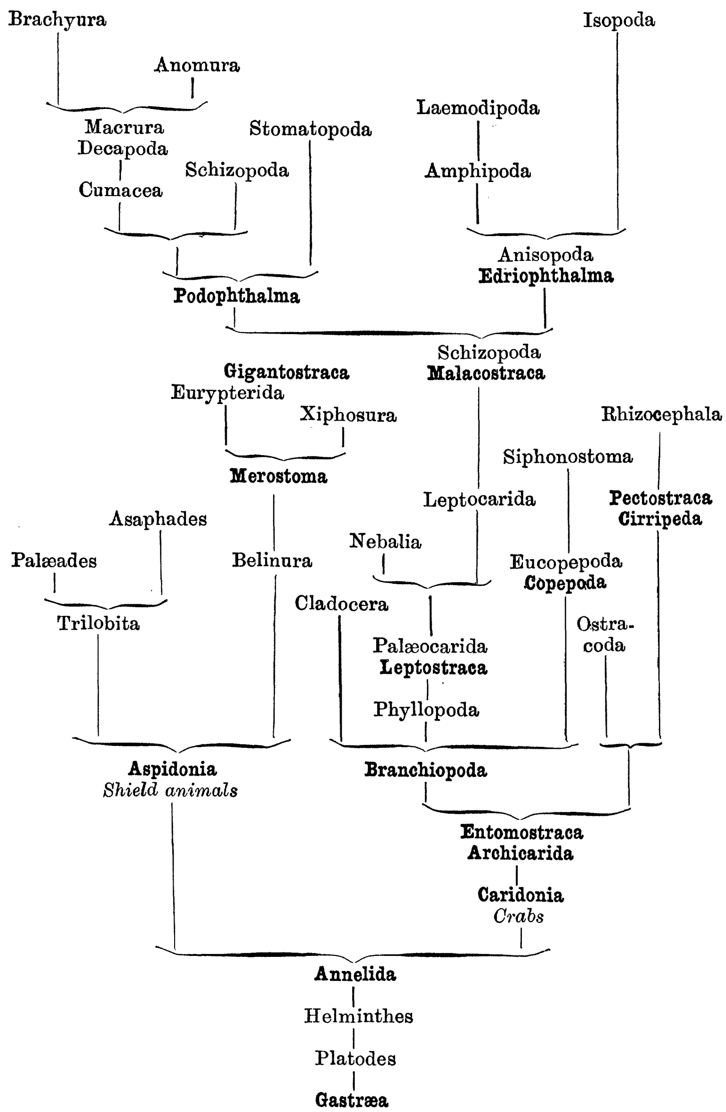
In the ontogeny of the Shield-animals (*Aspidonia*)—the second class of Crustacea—we do *not* find the characteristic Nauplius-larva, from which we can with certainty infer the common derivation of all the Crabs or Caridonia. And the Aspidonia possess only *one pair* of feelers or antennæ, whereas the Caridonia invariably have *two pairs*. Further, the articulation of the body, as well as its inner structure, exhibits various striking differences. Nevertheless it is probable that the pedigree of both classes of Crustacea is connected down at the root. Other zoologists, it is true, set such value upon these differences, that they separate the Aspidonia entirely from the Crustacea, and class them with the Spiders (Arachnida). Of these latter the scorpions specially show striking resemblances to the Aspidonia. Now, as scorpions occur as early as the Silurian period, and are the oldest fossil Tracheata, a common origin for the two groups might still be conceivable. However, the Aspidonia do not possess either the tracheæ or the Malpighian tubes of the Arachnida, which are possessed both by the Arachnida and the other Tracheata.

Among the Primordial extinct Aspidonia we have the largest of all the Articulata, the Silurian and Devonian

SYSTEMATIC SURVEY

Of the Encrusted Animals or Crustacea.

Classes of the Crustacea.	*Legions of the Crustacea.*	*Orders of the Crustacea.*	*A Generic Name as Example.*
I. **Crabs** *Caridonia* With two pairs of antennæ, with Nauplius form of larva	I. *Branchiopoda* Gill-footed Crabs	1. Archicarides.	Archicaris.
		2. Phyllopoda.	Limnetis.
		3. Cladocera.	Dapnia.
		4. Ostracoda.	Cypris.
	II. *Copepoda* Oar-footed Crabs	5. Eucopepoda.	Cyclops.
		6. Siphonostoma.	Lernæocera.
		7. Branchiura.	Argulus.
	III. *Cirripeda* Barnacle Crabs	8. Pectostraca.	Lepas.
		9. Rhizocephala.	Sacculina.
	IV. *Leptostraca* Primæval Mailed Crabs	10. Leptocarida.	Nebalia.
		11. Palæocarida.	Ceratocaris.
	V. *Edriophthalma* Sessile-eyed Mailed Crabs	12. Amphipoda.	Gammarus.
		13. Læmodipoda.	Caprella.
		14. Anisopoda.	Tanais.
		15. Isopoda.	Oniscus.
	VI. *Podophthalma* Stalk-eyed Mailed Crabs	16. Cumacea.	Diastylis.
		17. Schizopoda.	Mysis.
		18. Stomatopoda.	Squilla.
		19. Decapoda.	Astacus.
II. **Shield Animals** *Aspidonia* With one pair of antennæ, without the Nauplius form of larva	VII. *Trilobita* Shield Animals without nippers	20. Palæades.	Paradoxides.
		21. Asaphades.	Asaphus.
	VIII. *Merostoma* Shield Animals with nippers	22. Gigantostraca.	Pterygotus.
		23. Xiphosura.	Limulus.


Brachyura
Isopoda
Anomura
Macrura
Decapoda
Cumacea
Schizopoda
Stomatopoda
Laemodipoda
Amphipoda
Anisopoda
Edriophthalma
Podophthalma
Schizopoda
Malacostraca
Gigantostraca
Eurypterida
Xiphosura
Merostoma
Rhizocephala
Siphonostoma
Leptocarida
Pectostraca
Cirripeda
Asaphades
Palæades
Trilobita
Belinura
Nebalia
Cladocera
Eucopepoda
Copepoda
Palæocarida
Leptostraca
Phyllopoda
Ostra-
coda
Aspidonia
Shield animals
Branchiopoda
Entomostraca
Archicarida
Caridonia
Crabs
Annelida
Helminthes
Platodes
Gastræa

Merostoma (*Eurypterida* and *Pterygotida*). Some of them, very like giant scorpions, attained a length of more than two metres; they were formerly regarded partly as fossil fish. Our present Horse-shoe crabs (Xiphosura), with spear-tails, appear to be closely related to those Giant crabs (Gigantostraca) by the single genus *Limulus*. In these "last of the Mohicans" of the mighty Aspidonia tribe, the shield-shaped body likewise attains a length of more than a foot. They live in the Mollucca Sea and on the east coast of North America, and are often seen in our aquariums, where their spear-tails and their peculiar swimming movements create interest. It is probable that all these Aspidonia are derived from the very ancient Trilobita (Palæades and Asaphades). Masses of them are found fossilized in the Cambrian and Silurian systems; in the Coal period they are already found to be dying out.

The third main class of Articulata is formed by the Air-breathers, or *Tracheata*. They are more closely allied to the first main class, the Annelids, and are closely allied to them by the Protracheata (Peripatus), which were formerly classed with the latter. The Tracheata came into existence, at the earliest, towards the end of the archæolithic period, for all of these animals (in contrast with the aquatic crabs) are originally inhabitants of land. It is evident that these air-breathers can have developed only during the course of the Silurian period, when terrestrial life first began. The earliest fossil Tracheatea is a Silurian scorpion (Eoscorpius); fossil remains of Spiders and Insects are met with as early as the Devonian system and in Coal.

On the origin and relationships of the Tracheata we have recently received important information through the curious

Peripatus, which had indeed been known for long, but has only quite recently been more closely examined by the naturalists of the *Challenger* Expedition, to whom we are indebted for so much. And it was Moseley who gave the Peripatus its natural position in the system, by discovering its air-tubes and its development. Formerly this remarkable animal, which creeps about the earth in the torrid zone, was classed among the Ringed Worms, and resembles them outwardly in the cylindrical form of its regularly ringed body. Its body consists of from twenty to thirty segments or metamera, and has as many short non-articulated pairs of feet with claws. The Peripatus also possesses numerous pairs of nephridia or "segmental kidneys," like genuine Annelids. Its head is but little developed. Irregularly distributed over the skin are numerous very fine air-tubes, leading into bunches of narrow air-tubes with no opening at the end. This points to the fact that in these Peripatida—which must be regarded as the sole remnant of the primæval Protracheata—the characteristic air-breathing organs originated out of the cutaneous glands of Annelids, to which group other parts of their organization also still show close affinities.

In the other three classes of Tracheata, the Myriapods, Arachnida, and Insects, the air-tubes or tracheæ are no longer irregularly distributed over the whole skin in numberless little bunches, but are regularly arranged in two longitudinal rows of larger bunches. These open outwardly on either side by a row of air-holes, by means of which air enters into the tubes that have no outlet. In each of the two longitudinal rows, the originally separate bunches are generally united by connecting tubes or

anastomoses; and owing to the fuller development and distribution of these latter, there arise two large longitudinal branches, which, in the case of many Insects, appear as the main part of the system of their air-tubes. The three classes of genuine Tracheata are further generally distinguished from the Protracheata (Peripatus) by two important peculiarities: the segmental kidneys of the latter have been lost by degeneration, or have become changed, by division of labour, into other organs; and the non-articulated foot-stumps have become articulated legs (see Plate XVIII., Fig. 10, 11).

The Centipedes (*Myriapoda*) are more closely allied to the Protracheata or Peripatida than any of the other Tracheata; and, like the Protracheata, they live in dark, damp places in and on the earth. There likewise the body still shows great resemblance to the Ringed Worms, being composed of a number of regularly formed pieces, all of which possess a pair of short legs with claws (Plate XVIII., Fig. 10). This original character is retained by the first order of the Centipedes—the *Chilopoda,* those with simple feet. In the second order, on the other hand, in the *Diplopoda,* those with double feet, every two rings of the body have become fused together, so that each ring apparently carries two pairs of feet. The number of these pairs of feet is often very great, from sixty to eighty, and in some cases even over a hundred. All the legs are distinctly articulated. The Chilopoda include the *Scolopendra* and *Polyzonias;* the Chilognatha, on the other hand, *Julus* and *Glomeris.*

Whereas among the Protracheata and Myriapoda the number of rings and pairs of legs of the elongated, worm-like body is invariably very large, this appears very much

reduced in the third class of the Tracheata—the Spiders (*Arachnida*). They are generally described as possessing four pairs of legs, in contrast to the invariably six-legged Insects. But, as the Scorpion-spiders and the Tarantulæ seem to prove, they, like the Insects, have only three genuine pairs of legs. The apparent fourth pair of legs of the spiders, the foremost pair, is in reality a pair of jaws. Among the still existing Spiders there is a small group which is probably very closely allied to the common primary form of the whole class; this is the order of Scorpion-spiders, or Solifugæ (Solpuga, Galeodes), of which several large species live in Africa and Asia, and are dreaded on account of their poisonous bite. Their body—as we suppose to have been the case in the common ancestor of the Spiders and Insects—consists of three distinct segments: (1) a head with a pair of antennæ (changed into "antennary jaws") and two pairs of jaws; (2) a thorax, on the three rings of which are attached three pairs of genuine legs; (3) and a many-jointed abdomen. In the articulation of their body the Solifugæ are, therefore, in reality more closely related to Insects than to other Spiders; only one pair of jaws has been lost. Owing to the similarity of this morphological articulation, we may perhaps assume that the Long Spiders, Spinning Spiders, and Tailor Spiders developed as three divergent branches out of the primæval Silurian Spiders, which were nearly related to the Solifugæ of the present day (see p. 255).

The Long Spiders (*Scorparia* or *Arthrogastres*) appear to be the older and more original forms; the earlier form of the articulated body has been better preserved by them than by the Round Spiders. The most important forms

of this sub-class are the *Scorpions*, which are connected with the Solifugæ by the Phrynidæ or Pedipalpi. Fossil scorpions (Eoscorpius) are met with in the Silurian period as the earliest fossil remains of genuine air-breathing animals; they occur much more frequently in Coal. The small Book-scorpions, which inhabit our libraries and herbariums, appear as a degenerate lateral branch of the true Scorpions. Midway between the Scorpions and the Round Spiders are the long-legged Tailor Spiders (*Opiliones*), which have possibly arisen out of a special branch of the Solifugæ. The Pycnogonida, or Nobody Crabs, and the Arctisca, or Bear-worms—which are still usually included among the Spiders—are either wholly degenerate Arachnida (without a vestige of air-tubes), or they must be excluded from this class. The former may perhaps be included among the Crustacea, the latter among the Ringed Worms.

The Spinning Spiders (*Araneæ*), the second sub-class of the Arachnida, are of a much later origin than the Scorpions. They are first met with in the Jurassic system. They have probably developed out of a branch of the Solifugæ, by the rings of the body having become more and more united with one another. In the true Spinning Spiders (Araneæ), which are admired on account of their delicate skill in weaving, the union of the joints of the trunk or metamera goes so far, that the trunk now consists of only two pieces—of a head-breast (cephalothorax), with jaws and four pairs of legs; and of a hinder body without appendages, where the spinning warts are placed. In the mites (Acaria), which have probably arisen by degeneration (especially by parasitism) out of a lateral branch of Spinning Spiders,

even these two trunk-pieces have become united, and now form an unsegmented mass.

An entirely different opinion has recently been brought forward by Ray Lankester, who opposes the view offered here, viz. that the Arachnida show a close blood-relationship to the Insects, and that they have developed with them out of the older class of the Myriapods (perhaps also out of two different groups of this class). According to Ray Lankester, the agreement in the articulation and in the structure of the body in Spiders and Insects is merely a secondary one, caused by convergence. On the other hand, the Arachnida (and in the first place the primary group, the Scorpions), he thinks, show the closest blood-relationship with the King-Crabs, the Aspidonia, which we have discussed above under the second class of the Crustacea (p. 243). In fact, there are many striking resemblances between the two classes. Nevertheless, it may be held that this resemblance may have been produced only by convergence (vol. i. p. 314).

We must specially emphasize the fact that the Arachnida agree with the true Tracheata in two very important characteristics—in the possession of air-tubes and of Malpighian tubes; whereas the Aspidonia do not show a trace of them. If there existed any direct phylogenetic connection between Aspidonia (Limulus, Eurypterus) and Arachnida (Scorpio, Thelyphonus), the most likely hypothesis would be, that the latter had developed out of the former as early as the Silurian period, quite independently of the three other classes of Tracheata. The tracheæ of the Arachnida would then have a different origin from those of the Myriapoda and Insects.

The fourth and last class of the Articulata breathing through tracheæ is that of the Insects (*Insecta* or *Hexapoda*), the largest of all classes of animals, and, next to that of the Mammalia, also the most important. Although Insects develop a greater variety of genera and species than all other animals taken together, yet these are all, in reality, only superficial variations of a single type, which is entirely and constantly preserved in its essential characteristics. In all Insects the three divisions of the trunk—head, breast (thorax), and hinder body—are quite distinct (see Plate XVIII., Fig. 11). The hinder body, or abdomen, has no articulated appendages. The central division, the breast, or thorax, has on its ventral side three pairs of legs, and, in most also, two pairs of wings on the back. It is true that in many Insects one or both pairs of wings have become reduced in size, or have even entirely disappeared; but their comparative anatomy distinctly shows that this deficiency has arisen only gradually by the degeneration of the wings, and that all the Insects existing at present are derived from a common primary form of insect which possessed three pairs of legs and two pairs of wings (compare vol. i. p. 326). A single exception is formed by the order of the Thysanura (Campodina and Collembola). In the case of these small insects the want of wings existed originally; these insects are the last remnant of an older non-winged primary form, which arose directly out of the Myriapoda. The *wings*, which so strikingly distinguish Insects from all other Articulata, are independent dorsal appendages, and probably arose originally out of the leaf-shaped *tracheate-gills*, which may be still observed in the larvæ of the ephemeral flies (Ephemera) which live in water.

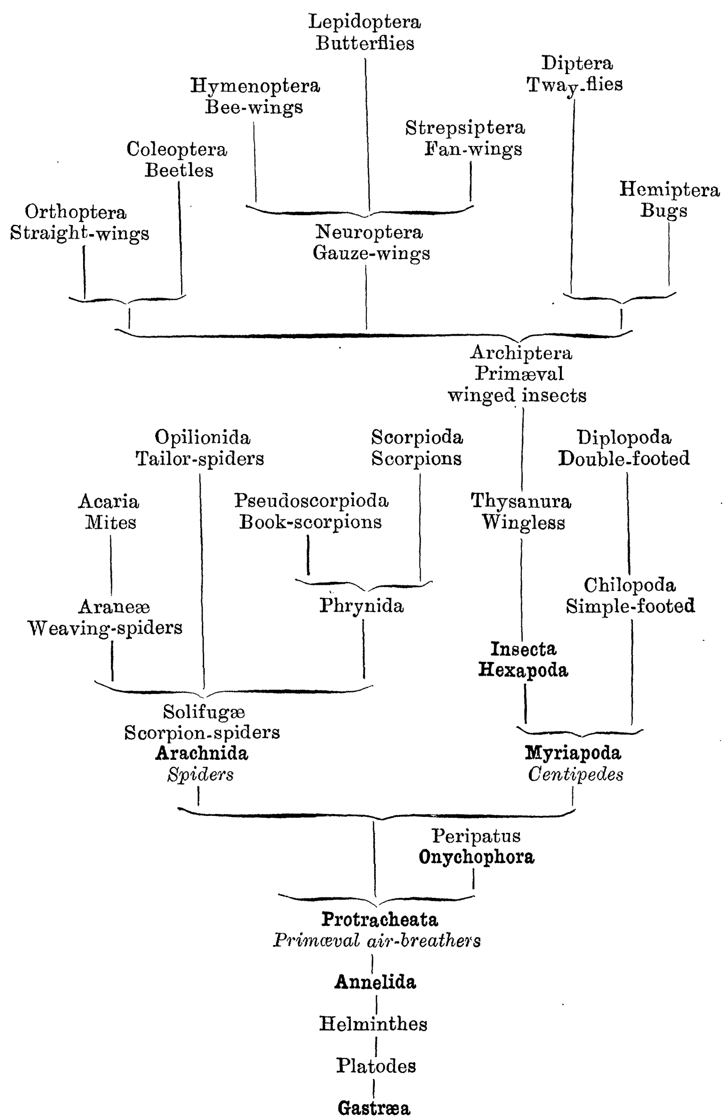
The head of Insects universally possesses, besides the eyes, a pair of articulated feelers or antennæ, and also three jaws upon each side of the mouth. These three pairs of jaws, although they have arisen in all Insects from the same original basis, by different kinds of adaptation, have become changed to very varied and remarkable forms in the various orders, and are therefore employed for distinguishing and characterizing the main divisions. In the first place, we may distinguish two main divisions of this rich class, namely, Insects with chewing mouths (Masticantia), and Insects with sucking mouths (Sugentia). On a closer examination, each of these two divisions may again be divided into two sub-groups. Among the chewing-insects, or Masticantia, we may distinguish the biting and licking group. The biting-insects (*Mordentia*) comprise the most ancient and primæval insects, the six orders of wingless insects, primæval winged insects, gauzy-winged, fan-winged, straight-winged insects, and beetles. The licking-insects (*Lambentia*) are represented by the one order of skin-winged insects. We distinguish two groups of sucking-insects (*Sugentia*), those which prick and those which sip. Of pricking-insects (*Pungentia*) there are two orders, those with half-wings and the tway-flies; of sipping-insects (*Sorbentia*) we have only the butterflies.

The order of wingless insects (*Thysanura*) must be considered the oldest of all the Insect tribe, and as nearest akin to the common primary form of the whole class; these include the small Campodea and Collembola (Spring-tails, Glacier-fleas, sugar-lice, silver-fish). They are distinguished above all other Insects by exhibiting the original simplicity of organization. The absence of wings is original only in

SYSTEMATIC SURVEY

Of the Air-breathing Articulata, or Tracheata.

Classes of the Tracheata.	*Sub-classes of the Tracheata.*	*Orders of the Tracheata.*	*Generic Name as Example.*
I. **Protracheata** *Primæval air-breathers*	I. Onychophora Worm-insects	1. Peripatida. Peripatids.	Properipatus. Peripatus.
II. **Myriapoda** *Centipedes*	II. Chilopoda Simple-footed	2. Chilopoda. Simple-footed.	Scolopendra. Geophilus.
	III. Diplopoda Double-footed	3. Diplopoda. Double-footed.	Julus. Polydesmus.
III. **Arachnida** *Spiders*	IV. Scorparia Long Spiders	4. Solifugæ. Scorpion-spiders.	Solpuga. Galæodes.
		5. Phrynida. Tarentella.	Phrynus. Thelyphonus.
		6. Scorpioda. Scorpions.	Scorpio. Buthus.
		7. Pseudoscorpioda. Book-scorpions.	Obisium. Chelifer.
		8. Opilionida. Tailor-spiders.	Phalangium. Opilio.
	V. Araneæ Spinning Spiders	9. Tetrapneumones. Four-lunged.	Mygale. Cteniza.
		10. Dipneumones. Two-lunged.	Epeira. Tegenaria.
	VI. Acaria Mites	11. Sphæracara. Round mites.	Sarcoptes. Demodex.
		12. Macracara. Long mites.	Linguatula. Pentastoma.
IV. **Insecta** or **Hexapoda** *Insects*	VII. Masticantia Chewing Insects	13. Thysanura. Wingless.	Campodea. Lepisma.
		14. Archiptera. Primæval insects.	Ephemera. Libellula.
		15. Neuroptera. Gauze-winged.	Hermerobius. Phryganea.
		16. Strepsipteria. Fan-winged.	Stylops. Xenos.
		17. Orthoptera. Straight-winged.	Locusta. Forficula.
		18. Coleoptera. Beetles.	Cicindela. Melolontha.
		19. Hymenoptera. Bee-wings.	Apis. Formica.
	VIII. Sugentia Sucking Insects	20. Hemiptera. Bugs.	Aphis. Cimex.
		21. Diptera. Tway-flies.	Culex. Musca.
		22. Lepidoptera. Butterflies.	Bombyx. Papilio.


Lepidoptera
Butterflies
Diptera
Tway-flies
Hymenoptera
Bee-wings
Strepsiptera
Fan-wings
Coleoptera
Beetles
Hemiptera
Bugs
Orthoptera
Straight-wings
Neuroptera
Gauze-wings
Archiptera
Primæval
winged insects
Opilionida
Tailor-spiders
Scorpioda
Scorpions
Diplopoda
Double-footed
Acaria
Mites
Pseudoscorpioda
Book-scorpions
Thysanura
Wingless
Araneæ
Weaving-spiders
Phrynida
Chilopoda
Simple-footed
Insecta
Hexapoda
Solifugæ
Scorpion-spiders
Arachnida
Spiders
Myriapoda
Centipedes
Peripatus
Onychophora
Protracheata
Primæval air-breathers
Annelida
Helminthes
Platodes
Gastræa

their case. In all other wingless insects (such as occur in numerous instances and in all the various orders) the absence of wings has originated only gradually by degeneration (see vol. i. p. 326). The Thysanura are further very remarkable by the fact that many of them (*e.g.* Campodea) have rudimentary legs on the rings of the hinder body, and hence show direct affinity to the Myriapods, their ancestors. On account of these important facts, the whole class of Insects can, from a phylogenetic point of view, be divided in the first place into two historically distinct sub-classes, the Apteronia and the Pterygonia. The older sub-class of the Primæval Wingless Insects (*Apteronia*) is now represented only by the Thysanura, and includes also the extinct direct intermediate forms between the Centipedes and Insects. The younger sub-class of Winged Insects (*Pterygonia*) developed at a later period out of the former, and includes all the other insects.

Of the Pterygonia, the oldest are the *Mordentia*, or the Insects with biting mandibles; and these latter include the Primæval winged insects (*Archiptera* or *Pseudoneuroptera*), which stand nearest the common primary form of all insects. To these belong, firstly, the Ephemeral Flies (Ephemera), whose larvæ, which live in water, in all probability still show us in their tracheal gills the organs out of which the wings of insects originally developed. This order further contains the well-known dragon-flies or Libellula, the hopping flies with bladder-like feet (Physopoda), and the dreaded white ants or Termites. Fossil remains of Primæval winged insects are found singly in the Devonian System and in Coal. The order of Gauze-winged insects (Neuroptera) probably developed directly out of

the Archiptera, which differ from them only by their perfect series of transformations. Among them are the gauze-flies (Planipennia) and the caddis-flies (Phryganida). Fossil insects, which form the transition from the Archiptera (Libella) to the Gauze-winged insects (Sialidæ), occur as early as the Devonian system and in Coal (Dictyophlebia). From the Neuroptera are probably descended the small fan-winged insects (Strepsiptera); distinguished by the degeneration of the fore wings and by their remarkable parasitical mode of life.

The order of Straight-winged insects (*Orthoptera*) developed at an early date out of another branch of the Archiptera by differentiation of the two pairs of wings. This division is composed of one group with a great variety of forms—cockroaches, grasshoppers, crickets, etc. (Ulonata), and of the smaller group of the well-known earwigs (Labidura), which are characterized by nippers at the hinder end of their bodies. Fossil remains of cockroaches, as well as of crickets and grasshoppers, have been found in the Devonian and the Coal systems.

The sixth and most highly developed order of the Biting-insects, that of the Beetles (*Coleoptera*), are likewise met with in Coal. This extremely comprehensive order—the favourite one of amateurs and collectors—shows more clearly than any other what infinite variety of forms can be developed externally by adaptation to different conditions of life without the internal structure and the original form of the body being in any way essentially changed. Beetles have probably developed out of a branch of the straight-winged insects, from which they differ only in their transformations.

The one order of Licking-insects, namely, the interesting group of the Bees or Skin-winged Insects (*Hymenoptera*), is closely allied to the six orders of Biting-insects. Among them are those insects which have risen to such an astonishing degree of mental development, of intellectual perfection, and strength of character, by their extensive division of labour, formation of communities and states, and surpass in this not merely most invertebrate animals, but even most animals in general. This may be said especially of all ants and bees, also of wasps, leaf-wasps, wood-wasps, gall-wasps, etc. They are first met with in a fossil state in the oolites, but they do not appear in great numbers until the tertiary period. Probably these insects developed either out of a branch of the primæval Insects or of the gauze-winged Insects.

Of the two orders of Pricking-insects (*Hemiptera* and *Diptera*), that containing the Half-winged Insects (*Hemiptera*), also called Beaked Insects (*Rhynchota*), is the older of the two. It includes three sub-orders, viz. the leaf-lice (*Homoptera*), the bugs (*Heteroptera*), and the lice (*Pediculina*). Fossil remains of the first two classes are found in the oolites; but a remarkable insect (*Eugereon*) is found in the Permian system, and seems to indicate the derivation of the Hemiptera from the Neuroptera. Probably the most ancient of the three sub-orders of the Hemiptera are the Homoptera, among which, besides the actual leaf-lice, are the shield-lice, leaf-fleas, and leaf-crickets, or Cicadæ. Lice have probably developed out of two different branches of Homoptera, by continued degeneration (especially by the loss of wings); bugs, on the other hand, by the perfecting and differentiation of the

two pairs of wings. Many of them (such as the bed-bug) have lost their wings.

The second order of Pricking-insects, namely, the Tway-flies (*Diptera*), are also found in a fossil state in the oolites, together with Hemiptera; but they probably developed out of the Hemiptera by the degeneration of the hind wings. In Diptera the fore wings alone have remained perfect. The principal portion of this order consists of the elongated gnats (Nemocera) and of the compact blow-flies and house-flies (Brachycera), the former of which are probably the older of the two. However, remains of both are found in the oolitic period. The two small groups of lice-flies (Pupipara) forming chrysales, and the hopping-fleas (Aphaniptera), probably developed out of the Diptera by degeneration resulting from parasitism.

The tenth and last order of Insects, and at the same time the only one with mouth-parts adapted to sipping liquids, consists of the butterflies (*Lepidoptera*). This order appears, in several morphological respects, to be the most perfect class of Insects, and accordingly was the last to develop. For we only know of fossil remains of this order from the tertiary period, whereas the three preceding orders extend back to the oolites, and the four biting orders even to the Coal or to the Devonian period. The close relationship between some moths (Tineæ and Noctuæ) and some caddis-flies (Phryganida) renders it probable that butterflies have developed from this group, that is, out of the order of the Gauze-winged Insects, or Neuroptera.

The whole history of Insects, and, moreover, the history of the whole tribe of the Articulata, essentially confirms the great laws of differentiation and perfecting which, according

to Darwin's theory of selection, must be considered as the necessary results of Natural Selection. The whole tribe, so rich in forms, begins in the Archæolithic period with the lower, aquatic Ringed animals, which arose out of an older group of non-articulated Worm-like animals. It was out of such old and still imperfectly articulated worms—which acquired the beginnings of the characteristic ventral nerve-cord—that the primary forms of our present Ring-worms (*Annelida*) were developed. They were at first still footless like the leeches; subsequently they acquired stump-feet with bristles like the bristle-footed worms. In like manner, as early as the Archæolithic period, and indeed in the Cambrian system, were developed by their side the Crustacea, or Encrusted Animals. Of these the Shield-animals, and especially the Tribolites, are represented by numerous fossils as early as the Devonian and Silurian systems, nay, even as early as in the Cambrian. Equally old are the Primæval Crabs, or Archicarida, and their descendants, the Leptocarida and Palæocarida.

The Air-Breathers, or Tracheata, are of a more recent origin than the water-breathing Ringed and Encrusted Animals. Some scorpions are indeed met with in the Silurian; and probably it is to the Silurian period that we have likewise to assign the common primary form of all the Tracheata, which was very likely akin to our present Peripatus. Out of these Protracheata there developed, during the Silurian and Devonian period, the ancestral forms of the Myriapoda, the Arachnida, and the Insects, which are found fossil in the Devon and Coal. Of Insects there existed for a long period only the six biting orders; at first wingless Thysanura, then the Archiptera, which probably

form the common primary group of the others. It was only at a much later period that the Licking, Pricking, and Sipping insects developed out of the Biting ones, which distinctly retained the original form of the three pairs of jaws. The following table will show once more how these orders succeeded one another in the history of the earth.

TABULAR SURVEY

Of the Historical Succession in the Palæontological Appearance of the Ten Orders of Insects.

A. **Insects with Chewing Mouths** *Masticantia*	I. Biting Insects *Mordentia*	1. Thysanura Wingless	M.I. A.O.	First fossil in the Devonian System
		2. Archiptera Primæval winged	M.I. A.A.	
		3. Neuroptera Gauze-winged	M.C. A.A.	
		4. Orthoptera Straight-winged	M.I. A.D.	
		5. Strepsiptera Fan-winged	M.C. A.D.	First fossil in Coal
		6. Coleoptera Beetles	M.C. A.D.	
	II. Licking Insects *Lambentia*	7. Hymenoptera Skin-winged	M.C. A.A.	First fossil in the Jura
B. **Insects with Sucking Mouths** *Sugentia*	III. Pricking Insects *Pungentia*	8. Hemiptera Half-winged	M.I. A.A.	
		9. Diptera Two-winged	M.C. A.D.	
	IV. Sipping Insects *Sorbentia*	10. Lepidoptera Butterflies	M.C. A.A.	First fossil in the Tertiary

Note.—In the Ten Orders of Insects, the difference in the metamorphosis or transformation, and in the development of the wings, is indicated by the following letters: M.I. = Imperfect Metamorphosis. M.C. = Complete Metamorphosis (see my "General Morphology," vol. ii. p. 99). A.A. = Equal Wings (fore and hinder wings are the same in structure and texture, or differ but little). A.D. = Unequal Wings (fore and hinder wings very different in structure and texture, occasioned by strong differentiation). A.O. = Original Absence of Wings (met with only in the first and oldest order of Insects, the Thysanura).

CHAPTER XXIV.

PEDIGREE AND HISTORY OF THE CHORDONIA, OR CHORDATA.

THE TUNICATES AND VERTEBRATES.

The Records of the Creation of Vertebrate Animals (Comparative Anatomy, Embryology, and Palæontology).—The Natural System of Vertebrate Animals.—The Four Classes of Vertebrate Animals, according to Linnæus and Lamarck.—Their increase to Eight Classes.—Main Class of the Tube-hearted, or Skull-less Animals (the Lancelet).—Blood-relationship between the Skull-less Fish and the Tunicates.—Agreement in the Embryological Development of Amphioxus and Ascidiæ.—Origin of the Vertebrate Tribe out of the Worm Tribe.—Monophyletic Descent of the Chordonia.—Their Branchial Gut.—Their Relation to the Enteropneusta (Tongue-worms, or Balanoglossus) and to the Cord-worms (Nemertina).—Divergent Development of the Tunicates and the Vertebrates.—The Three Classes of Tunicates: Copelata, Ascidiæ, and Thalidiæ.—Main Class of Single-nostriled Animals, or Round-mouths (Hags and Lampreys).—Main Class of the Non-amniote Animals (Ichthyota).—Fishes (Primæval Fish, Ganoid Fish, and Osseous Fish).—Mud-fish, or Dipneusta.—One-lunged (Monopneumones) and Two-lunged Fish (Dipneumones).

NOT one of the natural groups of organisms—which we have designated as tribes, or phyla, on account of the blood-relationship of all the species included in them—is of such great and exceeding importance as the tribe of Vertebrate Animals. For, according to the unanimous opinion of all zoologists, man also is a member of the tribe; and his whole organization and development cannot possibly be

distinguished from that of other Vertebrate animals. But as, from the individual history of human development, we have already recognized the undeniable fact that, in developing out of the egg, man at first does not differ from other Vertebrate animals, and especially from Mammals, we must necessarily come to the conclusion, in regard to the palæontological history of his development, that man has, historically, actually developed out of the lower Vertebrata, and that he is directly derived from lower Mammals. This circumstance, together with the many high interests which, in other respects, entitle the Vertebrata to more consideration than other organisms, justifies us in examining the pedigree of the Vertebrata and its expression in the natural system, with special care.

Fortunately, the records of creation, which must in all cases be our guide in establishing pedigrees, are especially complete in this important animal tribe, from which our own race has arisen. Even at the beginning of our century Cuvier's comparative anatomy and palæontology, and Bär's ontogeny of the Vertebrate animals, had brought us to a high level of accurate knowledge on this matter. Since then it is especially through Johannes Müller's and Rathke's investigations in comparative anatomy, and most recently through those of Gegenbaur and Huxley, that our knowledge of the natural relationships among the different groups of Vertebrata has become enlarged. It is especially Gegenbaur's classical works, penetrated as they are throughout with the fundamental principles of the Theory of Descent, which have demonstrated that the material of comparative anatomy receives its true importance and value only by the application of the Theory of Descent, and this in the case

of all animals, but especially in those of the Vertebrate tribe. Here, as everywhere else, analogies must be traced to Adaptation, homologies to Transmission by Inheritance. When we see that the limbs of the most different Vertebrata, in spite of their exceedingly different external forms, nevertheless possess essentially the same internal structure; when we see that in the arm of a man and ape, in the wing of a bat or a bird, in the breast-fins of whales and sea-dragons, in the fore legs of hoofed animals and frogs, the same bones always lie in the same characteristic position, articulation and connection—we can only explain this wonderful agreement and homology by the supposition of a common transmission by inheritance from a single primary form. On the other hand, the striking differences of these homologous bodily parts proceed from adaptation to different conditions of existence (compare Plate IV.).

Ontogeny, or the individual history of development, like comparative anatomy, is of especial importance to the pedigree of the Vertebrata. The first stages of development arising out of the egg are essentially identical in all Vertebrate animals, and retain their agreement the longer, the nearer the respective Vertebrate animal-forms, when fully developed, stand to one another in the natural system, that is, in the pedigree. How far this agreement of germ forms, or embryos, extends, even in the most highly developed Vertebrate animals, I have already had occasion to explain (vol. i. pp. 332–353). The complete agreement in form and structure, for example, in the embryos of a man and a dog, of a bird and a tortoise, existing in the stages of development represented on Plates II. and III., is a fact of incalculable importance, and furnishes us

with the most important data for the construction of their pedigree.

Finally, the palæontological records of creation are also of especial value in the case of these same Vertebrate animals; for their fossil remains belong for the most part to the bony skeleton, a system of organs which is of the utmost importance for understanding their general organization. It is true that here, as in all other cases, the fossil records are exceedingly imperfect and incomplete, but more important remains of extinct Vertebrate animals have been preserved in a fossil state than of most other groups of animals; and single fragments frequently furnish the most important hints as to the relationship and the historical succession of the groups.

The name of Vertebrate Animals (*Vertebrata*), as I have already said, originated with the great Lamarck, who towards the end of the last century comprised under this name Linnæus' four higher classes of animals, viz. Mammals, Birds, Amphibia, and Fishes. Linnæus' two lower classes, Insects and Worms, Lamarck contrasted to the Vertebrata, as *Invertebrata*, later also called *Evertebrata*.

The division of the Vertebrata into the four classes above named was retained also by Cuvier and his followers, and in consequence by many zoologists down to the present day. But in 1818 Blanville, the distinguished anatomist, found out by comparative anatomy—which Bär did almost at the same time from the ontogeny of Vertebrata—that Linnæus' class of Amphibia was an unnatural union of two very different classes. These two classes were separated as early as 1820, by Merrem, as two main groups of Amphibious animals, under the names of Pholidota and Batrachia.

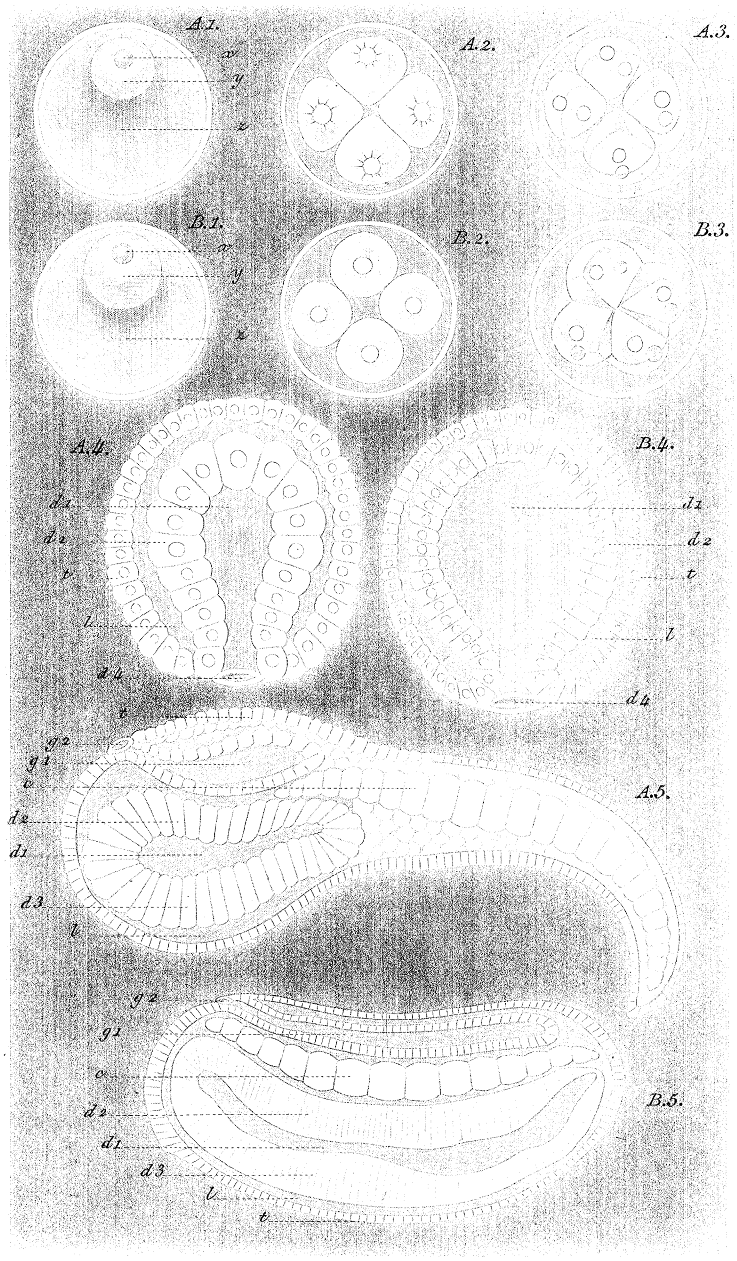
The *Batrachia*, which are at present (in a restricted sense) called Amphibia, comprise Frogs, Salamanders, gilled Salamanders, Cæcilia, and the extinct Stegocephala. Their entire organization is closely allied to that of Fishes. The *Pholidota*, or Reptiles, on the other hand, are much more closely allied to Birds. They comprise lizards, serpents, crocodiles, and tortoises, and the groups of the mesolithic Dragons, Sea-dragons, and Flying reptiles, etc.

In conformity with this natural division of the Amphibia into two classes, the whole tribe of Vertebrate animals was divided into two main groups. The first main group, containing Amphibia and Fishes, breathe throughout their lives, or in early life, by means of gills, and are therefore called Gilled Vertebrata (*Branchiata*, or *Anallantoidia*). The second main group—Reptiles, Birds, and Mammals—breathe at no period of their lives through gills, but exclusively through lungs, and hence may appropriately be called Gill-less, or lung-bearing Vertebrata (*Ebranchiata* or *Allantoidia*). However correct this distinction may be, still we cannot remain satisfied with it if we wish to arrive at a true natural system of the vertebrate tribe, and at a right understanding of its pedigree. In this case, as I have shown in my "General Morphology," we are obliged to distinguish three other classes of Vertebrate animals, by dividing what has hitherto been regarded as the class of fishes into four distinct classes ("Gen. Morph.," vol. ii. Plate VII. pp. 116–160).

The first and lowest of these classes comprises the Skull-less animals (*Acrania*), or animals with tubular hearts (*Leptocardia*), of which only one representative now exists, namely, the remarkable little Lancelet (*Amphioxus lanceo-*

latus). Nearly allied to this is the second class, that of the Single-nostriled animals (*Monorhina*), or Round-mouthed animals (*Cyclostoma*), which includes the Hags (*Myxinoidea*) and Lampreys (*Petromyzontia*). The third class contains only the genuine Fish (*Pisces*): the Mud-fishes (*Dipneusta*) are added to these as a fourth class, and form the transition from Fish to Amphibious animals. These distinctions, which, as will be seen immediately, are very important for the genealogy of the Vertebrate animals, increase the original number of Vertebrate classes from four to eight.

These eight classes of Vertebrate animals are, however, by no means of the same genealogical value. For important reasons we must divide them into four distinct main classes or tribes. In the first place, the three highest classes, Mammals, Birds, and Reptiles, may be comprised as a natural main class under the name of Amnion animals (*Amniota*). The Amnion-less animals (*Anamnia*), or fish-like animals (*Ichthyota*), naturally opposed to them as a second main class, include the three classes of Batrachians, Mud-fish, and Fishes. The six classes just named, the Anamnia as well as the Amniota, agree among one another in numerous characteristics, which distinguish them from the two lowest classes (the single-nostriled and tubular-hearted animals). Hence we may unite them in the natural main group of Double-nostriled animals (*Amphirhina*), or "Jaw-mouths" (*Gnathostoma*). Finally, these Amphirhina on the whole are much more closely related to those animals with round mouths or single nostrils than to the skull-less or tube-hearted animals. We may, therefore, with full justice class the single and double-nostriled animals into one principal main group, and contrast them as animals



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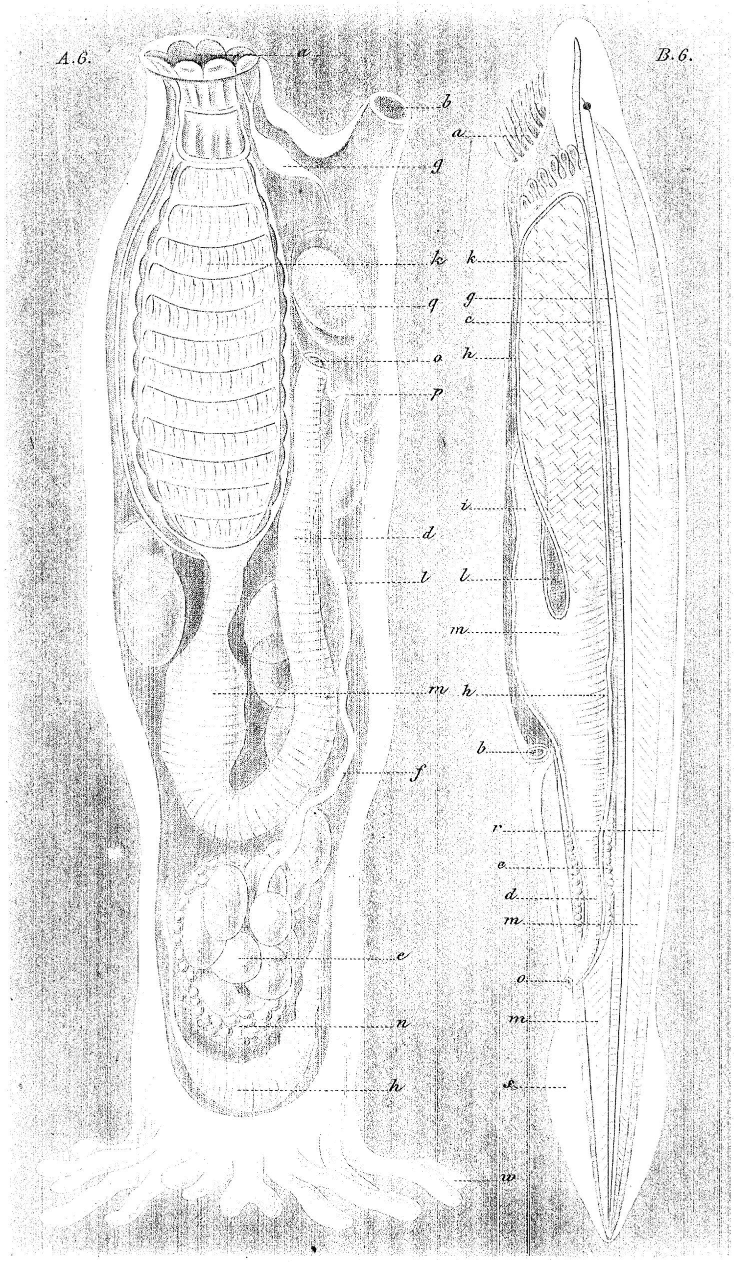

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with skulls (*Craniota*), or thick hearts (*Pachycardia*), to the one class of skull-less animals, or animals with tubular hearts. This classification of the Vertebrate animals proposed by me renders it possible to obtain a clear survey of the eight classes in their most important genealogical relations. The systematic relationship of these groups to one another may be briefly expressed by the following table :

A. Skull-less Animals **(Acrania)**			1. Tubular hearts	1. Leptocardia
B. Animals with Skulls **(Craniota)** or Thick Hearts **(Pachycardia)**	*a.* Single-nostriled animals *Monorhina*		2. Round-mouths	2. Cyclostoma
	b. Double-nostriled animals *Amphirhina* Gnathostoma	I. Non-Amnionate *Anamnia* (*Ichthyota*)	3. Fish	3. Pisces
			4. Mud-fish	4. Dipneusta
			5. Batrachians	5. Amphibia
		II. Amnionate. *Amniota*	6. Reptiles	6. Reptilia
			7. Birds	7. Aves
			8. Mammals	8. Mammalia

The only one representative of the first class, the small lanceolate fish, or Lancelet (*Amphioxus lanceolatus*) (Plate XIII., Fig. *B*), stands at the lowest stage of organization of all the Vertebrate animals known to us. This exceedingly interesting and important animal, which throws a surprising light upon the older roots of our pedigree, is evidently the "last of the Mohicans"—the last surviving representative of a lower class of Vertebrate animals, very rich in forms, and very highly developed during the primordial period, but which unfortunately could leave no fossil remains on account of the absence of all solid skeleton. The Lancelet

still lives widely distributed in different seas; for instance, in the Baltic, North Sea, and Mediterranean, where it generally lies buried in the sand on flat shores. The body, as the name indicates, has the form of a narrow lanceolate leaf, pointed at both extremities. When full grown it is about two inches long, of a white colour and semi-transparent. Externally, the little lanceolate animal is so little like a vertebrate animal that Pallas, who first discovered it, regarded it as an imperfect naked snail. It has no legs, and neither head, skull, nor brain. Externally, the fore end of the body can be distinguished from the hinder end only by the mouth orifice. But still the Amphioxus in its internal structure possesses those most important features which distinguish all Vertebrate animals from all Invertebrate animals, namely, the spinal rod and spinal marrow. The spinal rod (*notochord*) is a straight, cylindrical, cartilaginous staff, pointed at both ends, forming the central axis of the internal skeleton, and the basis of the vertebral column. Directly above the spinal rod, on its dorsal side, lies the spinal marrow (*medulla spinalis*), likewise originally a straight but internally hollow cord, pointed at both ends. This forms the principal piece and centre of the nervous system in all Vertebrate animals (Plate XIX., Fig. 21–23). In all Vertebrate animals without exception, man included, these important parts of the body during the embryological development out of the egg, originally begin in the same simple form, which is retained throughout life by the Amphioxus. It is only at a later period that the brain develops by the expansion of the fore end of the spinal marrow, whilst the skull which encloses the brain forms around the end of the notochord. As these two important

organs do not develop at all in the Amphioxus, we may justly call the class represented by it, Skull-less animals (*Acrania*), in opposition to all the others, namely, to the animals with skulls (*Craniota*). The Skull-less animals are generally called tubular-hearted (*Leptocardia*), because a centralized heart does not as yet exist, and the blood is circulated in the body by the contractions of the tubular blood-vessels themselves. The Skulled animals, which possess a centralized, thick-walled, bulb-shaped heart, ought then by way of contrast to be called thick-hearted animals (*Pachycardia*).

Animals with skulls and central hearts evidently developed gradually in the later primordial period out of those without skulls and with tubular hearts. Of this the ontogeny of skulled animals leaves no doubt. But whence are these same skull-less animals derived? It is only very lately that an exceedingly surprising answer has been given to this important question. From Kowalewsky's investigations, published in 1867, on the individual development of the Amphioxus and the adhering Sea-squirts (Ascidia) belonging to the class of mantled animals (Tunicata), a very surprising fact revealed itself, viz. that the ontogenies of these two entirely different-looking animal-forms agree in the first stage of development in a most remarkable manner. The freely swimming larvæ of the Ascidians (Plate XII., Fig. *A*) develop the undeniable beginning of a spinal marrow (Fig. 5 *g*) and of a notochord (Fig. 5 *c*), and this moreover in entirely the same way as does the Amphioxus (Plate XII., Fig. *B*). It is true that in the Ascidians these most important organs of the Vertebrate animal-body do not afterwards develop further. The Ascidians take on a

retrograde transformation, become attached to the bottom of the sea, and develop into shapeless lumps, which when looked upon externally would scarcely be supposed to be animals (Plate XIII., Fig. *A*). But the spinal marrow, as the beginning of the central nervous system, and the notochord, as the first basis of the vertebral column, are such important organs, so exclusively characteristic of Vertebrate animals, that we may from them with certitude infer the true blood-relationship of Vertebrate with Tunicate animals. Of course we do not mean to say by this that Vertebrate animals are derived from Tunicate animals, but merely that both groups have arisen out of a common root, and that the Tunicates, of all the Invertebrata, are the nearest blood-relations of the Vertebrates. It is quite evident that genuine Vertebrate animals developed progressively during the primordial period out of a group of worm-like Chordata, from which the degenerate Tunicate animals arose in another and a retrograde direction. (Compare the more detailed explanation of Plates XII. and XIII. in the Appendix; also the detailed account of the Amphioxus and of the Ascidians in the thirteenth and fourteenth Lectures of my "Anthropogeny.")

The large group of the *Chordonia* or *Chordata*, in which I include all animals with notochord and spinal marrow, has accordingly of late been regarded as a single main group of Cœlomaria. Their root is considered a common one, and is looked for far down in the pedigree of the Helminthes (see p. 96); for it cannot be supposed that so peculiar and complicated an arrangement in the structure of the body can have originated several times and independently. The great monophyletic group itself, however,

we regard as a double stem, for the considerable divergence of development has led to the conviction that Tunicates and Vertebrates separate very early above the common root, the former degenerating slowly, the latter advancing powerfully in the typical direction.

The common fundamental characteristics, in which all Tunicates and Vertebrates agree, and by which both classes differ absolutely from all other animals, are by no means confined to the possession of the notochord and spinal marrow. In fact, there are several other and no less important peculiarities. The most significant of these is the branchial gut, *i.e.* the transformation of the ventral side of the intestine into a latticed gill-basket intersected by slits that serve for respiration. The water which originally serves for breathing, enters by the mouth orifice and runs out again through the gill-clefts. Below, in the centre of the branchial gut lies a very characteristic ciliate tract, the "hypobranchial groove with the endostyle." In the Tunicates and Skull-less animals it serves as a glandular tract and organ of sense; in the Skulled animals, on the other hand, it becomes the thyroid gland, the gland that lies in front of the larynx, which, when increased in size by disease in man, gives rise to goitre or struma. A similar arrangement, namely, the original arrangement of the branchial gut, occurs now only in one single species of invertebrate animal, the curious Tongue-worm (Balanoglossus). As it shows other traces of blood-relationship with the Chordonia, we may regard it as the last remnant of a primordial class of worms, from which all Chordonia are derived. This class Gegenbaur has admirably designated as Enteropneusta, "gut-breathers." The pedigree of these

"gut-breathers," both the Enteropneusta and the Chordonia, must in any case be traced back to a group of Worms standing lower down; it is probable that, of all the still living Helminthes, the curious Cord-worms (Nemertina) stand most closely allied to that extinct primary group. Accordingly, in the System of the Helminthes, given on p. 198, I have placed the two classes of the Enteropneusta and Nemertina together in the main class of the Proboscideans (Rhynchocœla). The earlier ancestors of this main class must again be looked for among the Flat-animals (Platodes), as is evident from the close relationship between the latter and the Nemertina.

The common primary form of all Chordonia, which was closely allied to the Balanoglossus, has long since become extinct. We will give this hypothetical primary group—which probably existed as early as the Laurentian or Cambrian periods—the name of Primæval Chordate Animals (Prochordata or Prochordonia). Out of them arose, as two diverging branches, the earliest Tunicates (Copelata) on the one hand, and the earliest Vertebrates (Provertebrata) on the other. All of these earliest Chordonia had the following characteristics in common: (1) a simple rod or notochord in the longitudinal axis of the elongated, bilaterally symmetrical body; (2) spinal marrow or medullary canal above the notochord on the dorsal side; (3) an intestinal tube with mouth and anus below the notochord on the ventral side; (4) gill-clefts in the fore part of the intestine; (5) a ventral gill-groove or hypobranchial tract in the ventral line of the branchial gut; (6) a pair of cœlmic pouches at both sides of the central intestine; (7) nephridia or renal organs in pairs, which open inwardly into the cœlmic cavity, outwardly

through the wall of the body; (8) a simple ventral heart behind the gill-clefts on the ventral side of the front intestine (Plate XIX., Fig. 19–23). These characteristic peculiarities which the Primæval Chordonia have in common, were for the most part transmitted, by inheritance, to the two diverging branches of the Tunicates and the Vertebrates, whereas the smaller portion of their characteristics became peculiarly changed, partly modified by progression, partly by degeneration. In the case of the Tunicates the branchial gut became immoderately developed, whereas the dorsal neural tube became degenerated, and besides this they developed a peculiar external mantle-covering. In the Vertebrates, on the other hand, the spinal marrow and the muscular articulation of the body became more highly developed, while the branchial gut degenerated, and, besides this, they developed a peculiar internal skeleton out of the sheath of the notochord.

The tribe of Mantled animals (*Tunicata*) used formerly to be placed either among the Molluscs or among the Helminthes. Now it is very justly regarded as an important independent main group of the Cœlomaria, and placed next to the Vertebrates. All Tunicates live in the sea, where some adhere to the bottom, while others swim about freely. In all of them the non-jointed body has the form of a simple barrel-shaped sack, which is surrounded by a thick cartilaginous mantle. This mantle (*Tunica*) consists of the same non-nitrogenous combination of carbon, which, under the name of cellulose, plays an important part in the vegetable kingdom, and forms the largest portion of vegetable cellular membranes, and consequently also the greater part of wood. In an historical respect also, the

mantle is very remarkable; its structure is that of connective tissue, although originally separated from the upper skin on its outer surface. The larger part of this sack-shaped mantled cavity (often more than three-fourths) is occupied by the huge branchial gut. Below it lies the spindle-shaped heart, the pulsation of which continually changes its direction in a very remarkable manner; the heart contracts—at definite intervals—alternately, first in the direction of from back to front, and then *vice versâ.*

The various and rather divergent families of the Tunicate tribe may be divided into three classes, the Copelata, Ascidiæ, and the Thalidiæ. The first and lowest class is formed by the small *Appendicularia* (Copelata); they have the form and the movements of tadpoles, and swim about freely in the sea by means of a rudder-tail, in the centre of which lies the permanent notochord (Plate XIX., Fig. 19). In the second class, that of the Sea-squirts, or Ascidiæ, the rudder-tail exists only in the larval stages, in the freely swimming larva (Plate XII., Fig. *A* 5); subsequently it is cast off; the larva settles down, becomes adherent, and degenerates in a peculiar manner. In the third class, that of the Salpaceæ, or Thalidiæ (Salpa, Doliolum), the rudder-tail has disappeared entirely; the animals move about, swimming by drawing in water into their barrel-shaped body and then ejecting it.

The two classes of Ascidiæ and Thalidiæ have obviously developed, divergently, out of a common older group of the extinct Tunicatæ, of which the present Copelata (Appendicularia, Œcopleura) represented the last remnant. As these latter show close affinity to the Primæval Vertebrates, they

may be included with them in the primary group of the Prochordonia. The still living Amphioxus gives a tolerably faithful picture of the organization of the Primæval Vertebrates, or Provertebrata. Still, in judging of the comparative anatomy of these earliest Chordata, it must be remembered that the Lancelet has in many respects considerably degenerated, by adaptation, to its peculiar mode of life. We consider, for instance, the absence of a ventral heart, kidneys, and auditory organ, secondary manifestations of a lower organization which have originated from degeneration. But in by far the most important respects, the lower organization of the Amphioxus must be regarded as a primary one, as an inestimable prototype of the Provertebrata, which has been preserved to us by inheritance.

Out of the Skull-less animals there developed, in the first instance, a second low class of Vertebrate animals, still far below that of fish, and which is now represented only by the Hags (Myxinoidea) and Lampreys (Petromyzontia). This class also, on account of the absence of all solid parts, could, unfortunately, as little as the Skull-less animals, leave fossil remains. From its whole organization and ontogeny it is quite evident that it represents a very important intermediate stage between the Skull-less animals and Fishes, and that its few still existing members are only the last surviving remains of a very highly developed animal group which existed towards the end of the primordial period. On account of the curious mouth possessed by Hags and Lampreys, which they use for sucking, the whole class is usually called Round-mouthed animals (*Cyclostoma*). The name of Single-nostriled animals (*Monorhina*) is still more characteristic; for all Cyclostoma

possess a simple single nasal tube, whereas in all other Vertebrata (with the exception of the Amphioxus) the nose consists of two lateral halves, a right and a left nostril. We are, therefore, enabled to comprise these latter (Anamnia and Amniota) under the heading, Double-nostriled animals (*Amphirhina*). All the Amphirhina possess a fully developed jaw-skeleton (upper and lower jaw), whereas it is completely wanting in the Monorhina.

Apart, also, from the peculiar nasal formation, and the absence of jaws, the Single-nostriled animals are distinguished from those with double nostrils by many peculiarities. Thus they want the important sympathetic nervous system possessed by the latter. Of the swimming-bladder, and the two pairs of legs—which all double-nostriled animals have, at least in their embryonic conditions—not a trace exists in the single-nostriled animals, which is the case also in the Skull-less animals. Hence we are surely justified in completely separating the Monorhina, as well as the Skull-less animals, from the Fishes, with which they have hitherto been erroneously classed. Moreover, we must not regard all the imperfect and simple arrangements in the structure of the body of the Round-mouthed animals and of the Amphioxus as original, and as having been transmitted by inheritance from their ancestors of the Chordonia group; on the contrary, part of them probably arose at a later period by adaptation to the peculiar mode of life of these lowest Vertebrate animals, hence as a result of degeneration.

We owe our first accurate knowledge of the Monorhina, or Cyclostoma, to the great zoologist, Johannes Müller of Berlin; his classical work on the "Comparative Anatomy of the Myxinoidea" forms the foundation of our modern

views on the structure of the Vertebrate animals. He distinguished two distinct groups among the Cyclostoma, which we shall consider as sub-classes: Myxinoidea and Petromyzontia.

The first sub-class consists of the Hags (Hyperotreta, or Myxinoidea). They live in the sea as parasites upon other fish, into whose skin they penetrate (Myxine, Bdellostoma). Their organ of hearing has only one annular canal, and their single nasal tube penetrates the palate. The second sub-class, that of Lampreys, or Prides (Hyperoartia, or Petromyzontia), is more highly developed. It includes the well-known Lamperns, or Nine-eyes, of our rivers (Petromyzon fluviatilis), with which most persons are acquainted. They are represented in the sea by the frequently larger marine or genuine Lampreys (Petromyzon marinus). The nasal tube of these single-nostriled animals does not penetrate the palate, and in the auricular organ there are two annular canals. They also possess a round sucking-mouth with horny teeth, by means of which, like leeches, they attach themselves to fish. The parasitical mode of life of the Cyclostoma is obviously the cause of many a degeneration in their organization; however, most of the differences between them and fish must be conceived of as original and as inherited from the earlier primary group. The opinion of some zoologists that the Cyclostoma and Acrania are degenerate fish, is not supported by a single fact in comparative anatomy or ontogeny.

All existing Vertebrate animals, with the exception of the Monorhina and Amphioxus just mentioned, belong to the group which we designate as Double-nostriled animals (Amphirhina), or "Jaw-mouths" (Gnathostoma). All these

SYSTEMATIC SURVEY

Of the Main-classes, Classes, and Sub-classes of Vertebrata.

"Gen. Morph.," vol. ii. Plate VII. pp. 116–160.

I. Skull-less (**Acrania**), *or* Tube-hearted (**Leptocardia**).

Vertebrata without head, without skull and brain, without centralized heart.

1. Skull-less **Acrania**	I. Tube-hearted *Leptocardia*	1. Primæval Vertebrata 2. Lancelet	1. Provertebrata 2. Amphioxus

II. Animals with Skulls (**Craniota**) and with thick-walled hearts (**Pachycardia**).

Vertebrata with head, with skull and brain, with centralized heart.

Main-classes of the Skulled Animals.	*Classes of the Skulled Animals.*	*Sub-classes of the Skulled Animals.*	*Systematic Name of the Sub-classes.*
2. Single-Nostriled **Monorhina**	II. Round mouths *Cyclostoma*	3. Hags.	3. Hyperotreta (Myxinoidea).
		4. Lampreys, or Pride.	4. Hyperoartia (Petromyzontia).
3. Non-amnionate **Anamnia**	III. Fish *Pisces*	5. Primæval fish.	5. Selachii.
		6. Ganoid fish.	6. Ganoides.
		7. Osseous fish.	7. Teleostei.
	IV. Mud-fish *Dipneusta*	8. One-lunged.	8. Monopneumones.
		9. Two-lunged.	9. Dipneumones.
	V. Batrachians *Amphibia*	10. Mailed batrachians.	10. Stegocephala.
		11. Snake-batrachians.	11. Gymnophiona.
		12. Tailed batrachians.	12. Urodela.
		13. Frog-batrachians.	13. Batrachia.
4. Amnion Animals **Amniota**	VI. Reptiles *Reptilia*	14. Land-reptiles.	14. Geosauria.
		15. Sea-reptiles.	15. Halisauria.
		16. Tortoises.	16. Chelonia.
		17. Flying reptiles.	17. Pterosauria.
	VII. Birds *Aves*	18. Primæval birds.	18. Saururæ.
		19. Toothed birds.	19. Odontornithes.
		20. Ostriches.	20. Ratitæ.
		21. Fan-tailed.	21. Carinatæ.
	VIII. Mammals *Mammalia*	22. Cloacal animals.	22. Monotrema.
		23. Pouched animals.	23. Marsupialia.
		24. Placental animals.	24. Placentalia.

8. Mammals
Mammalia

7. Birds (Aves)

6. Reptiles (Reptilia)

Two-lunged
Dipneumones

Proreptilia (Protamnia)
Amnion animals (Amniota)

One-lunged
Monopneumones

Comb-fish
Ctenodipterini

5. Batrachians
Amphibia

Osseous fish
Teleostei

4. Mud-fish
Dipneusta

Ganoid fish (Ganoides)

Lampreys
Petromyzontes

Primæval fish (Selachii)
3. Fish (Pisces)

Hags
Myxinoidea

" Jaw-mouths "
Gnathostoma

2. Round-mouthed
Cyclostoma

Mantled animals
Tunicata

Skulled animals (Craniota)

Thalidiæ Ascidiæ

1. Tube-hearted
Leptocardia

Primæval vertebrates
Provertebrata

Copelata

Skull-less animals (Acrania)
Vertebrate animals (Vertebrata)

Tongue-worms
Enteropneusta

Chord-animals (Chordonia)

Worms (Helminthes)

Flat-animals (Platodes)

Gastræa

animals possess (in spite of the great variety in the rest of their forms) a nose consisting of two lateral halves, a jaw-skeleton, a sympathetic nervous system, and three annular canals in the auditory organ. Further, all Double-nostriled animals possess a bladder-shaped expansion of the gullet, which, in Fish, has developed into the swimming-bladder, but in all other Gnathostoma into lungs. Finally, in all Double-nostriled animals there exist in the youngest stage of growth the beginnings of two pairs of extremities, or limbs, a pair of fore legs, or breast fins, and a pair of hinder legs, or ventral fins. One of these pairs of legs sometimes degenerates (as in the case of eels, whales, etc.), or both pairs of legs (as in Cæciliæ and Serpents) either degenerate or entirely disappear; but even in these cases there exists some trace of their original beginning in an early embryonic period, or the useless remains of them may be found in the form of rudimentary organs (compare vol. i. pp. 14, 352, and Plate XIX. Fig. 21–23).

From all these important indications we may conclude with full assurance that all Gnathostoma are derived from a single common primary form, which developed either directly or indirectly during the primordial period out of the Cyclostoma. This primary form must have possessed the organs above mentioned, and also the beginning of a swimming-bladder and of two pairs of legs or fins. It is evident, that of all still living double-nostriled animals, the lowest forms of sharks are most closely allied to this long since extinct, unknown, and hypothetical primary form, which we may call the Primary Double-nostriled animals (Proselachii). We may therefore look upon the group of primæval fish, or Selachii, to which the *Proselachii*

probably belonged, as a primary group, not only of the Fish class, but of the whole main class of double-nostriled animals. A certain proof of this is furnished by Carl Gegenbaur's "Investigations in the Comparative Anatomy of the Vertebrata," which are as admirable for careful observation as for astute reflection.

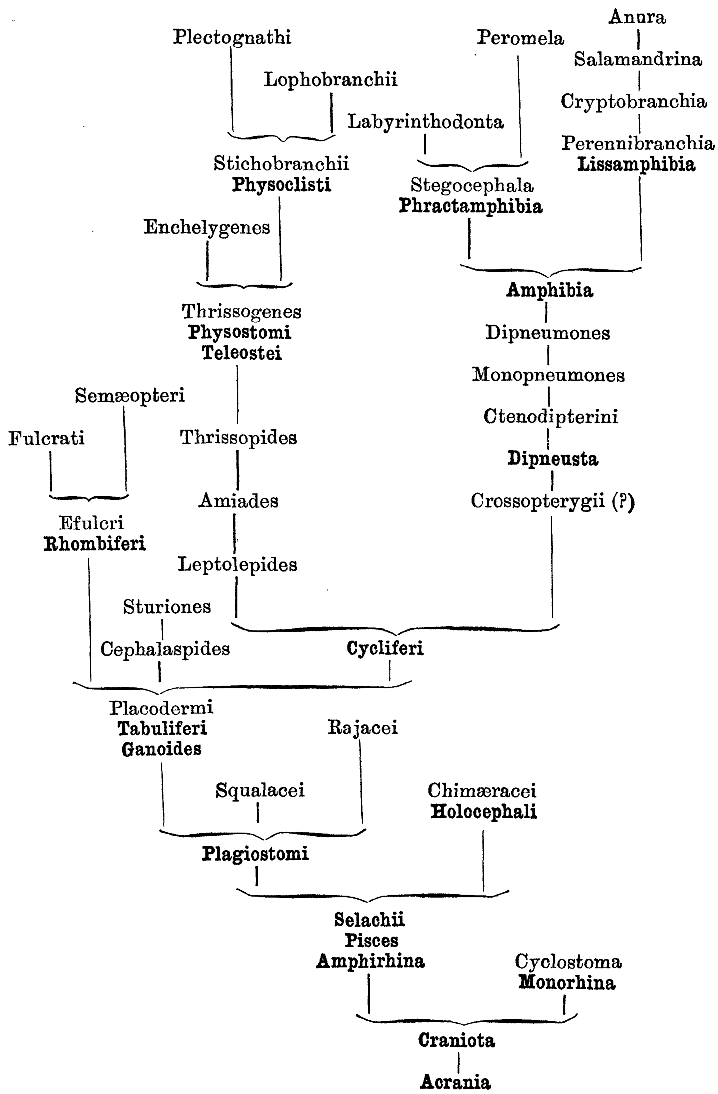
The class of *Fish* (Pisces) with which we accordingly begin the series of the Gnathostoma, is distinguished from the other five classes of the series principally by the swimming-bladder never developing into lungs, but acting only as a hydrostatic apparatus. Agreeing with this, we find that in fish the nose is formed by two blind holes in front of the mouth, which never pierce the palate so as to open into the cavity of the mouth. In the other six classes of Gnathostoma, both nostrils are changed into air-passages which pierce the palate, and thus conduct air to the lungs. Genuine fish (after the exclusion of the Dipneusta) are accordingly the only double-nostriled animals which exclusively breathe through gills and never through lungs. In accordance with this, they all live in water, and both pairs of their legs have retained the original form of paddling fins. Their heart is divided into an auricle and a ventricle, and contains only venous or carbonic blood, as in the case of the Cyclostoma. Driven out of the veins of the body, the blood is thence driven directly into the gills (Ichthyocardia, p. 291).

Genuine fish are divided into three distinct sub-classes, namely, Primæval fish, Ganoid fish, and Osseous fish. The oldest of these, where the original form has been most faithfully preserved, is that of the *Primæval fish* (Selachii). Of these there still exist Sharks (Squali), and Rays (Rajæ),

SYSTEMATIC SURVEY

Of the 7 Legions and 15 Orders of the Fishes.

Sub-classes of Fishes.	*Legions of Fishes.*	*Orders of Fishes.*	*Examples from the Orders.*
A. Primæval Fish **Selachii**	I. Transverse mouths *Plagiostomi*	1. Sharks. *Squalacei.*	Sharks, dog-fish.
		2. Rays. *Rajacei.*	Skates, rays, electric rays, etc.
	II. Sea-Cats *Holocephali*	3. Sea-Cats. *Chimæracei.*	Chimæra, Calorrhynchus.
B. Ganoid Fish **Ganoides**	III. Mailed Ganoid Fish *Tabuliferi*	4. Buckler-heads. *Placodermi.*	Cephalaspidæ, Pteraspidæ, etc.
		5. Sturgeons. *Sturiones.*	Spoon-sturgeons, sturgeons, sterlet, etc.
	IV. Angular-scaled Ganoid Fish *Rhombiferi*	6. *Efulcri.*	Double-finned.
		7. *Fulcrati.*	Palæoniscus, bony pike, etc.
		8. *Semœopteri.*	African finny pike, etc.
	V. Round-scaled Ganoid Fish *Cycliferi*	9. *Crossopterygii.*	Holopytchius, Cœlacanthides, etc.
		10. *Amiades.*	Coccolepida, Leptolepidæ, etc.
C. Osseous Fish **Teleostei**	VI. Osseous Fish with an air-passage to the swimming-bladder *Physostomi*	11. Herring kind. *Thrissogenes.*	Herring, salmon, carp, etc.
		12. Eel kind. *Enchelygenes.*	Eels, snake eels, electric eels, etc.
	VII. Osseous Fish without an air-passage to the swimming-bladder *Physoclisti*	13. *Stichobranchii.*	Perch, wrasse, turbot, etc.
		14. *Plectognathi.*	Trunk-fish, globe-fish, etc.
		15. *Lophobranchii.*	Pipe-fish, sea-horses, etc.


Anura
Salamandrina
Cryptobranchia
Perennibranchia
Lissamphibia
Plectognathi
Peromela
Lophobranchii
Labyrinthodonta
Stichobranchii
Physoclisti
Stegocephala
Phractamphibia
Enchelygenes
Amphibia
Thrissogenes
Physostomi
Teleostei
Dipneumones
Monopneumones
Semæopteri
Ctenodipterini
Fulcrati
Thrissopides
Dipneusta
Amiades
Crossopterygii (?)
Efulcri
Rhombiferi
Leptolepides
Sturiones
Cephalaspides
Cycliferi
Placodermi
Tabuliferi
Ganoides
Rajacei
Squalacei
Chimæracei
Holocephali
Plagiostomi
Selachii
Pisces
Amphirhina
Cyclostoma
Monorhina
Craniota
Acrania

which are classed together as cross-mouthed fishes (Plagiostomi), and the strange and grotesquely formed Sea-cats, or *Chimæracei* (Holocephali). These primary fish of the present day, which are met with in all seas, are only poor remains of the prevailing animal groups, rich in forms, which the Selachii formed in the earlier periods of the earth's history, and especially during the palæolithic period. Unfortunately all Primæval fish possess a cartilaginous, never a completely osseous skeleton, which is but little, if at all, capable of being petrified. The only hard parts of the body which could be preserved in a fossil state, are the teeth and fin-spikes. These are found in the older formations in such quantities, varieties, and sizes, that we may, with certainty, infer a very considerable development of Primæval fish in those remote ages. They are even found in the Silurian strata, which contain but few remains of other Vertebrata. By far the most important and interesting of the three orders of Primæval fish are Sharks; of all still living double-nostriled animals, they are probably most closely allied to the original primary form of the whole group, namely, to the Proselachii. Out of these Proselachii, which probably differed but little from genuine Sharks, the present Primæval fish and Holocephali in all probability developed in one direction, and the Dipneusta, the Ganoides, and Amphibia in the other and higher direction.

The Ganoid, or Enamelled fish (*Ganoides*), in regard to their anatomy stand midway between the Primæval and the Osseous fish. In many characteristics they agree with the former, and in many others with the latter. Hence, we infer that genealogically they form the transition from Primæval to Osseous fish. The Ganoids are for the most part extinct,

and more nearly so than the Primæval fish, whereas they were developed in great force during the entire palæolithic and mesolithic periods. Ganoid fish are divided into three legions according to the form of their external covering, namely, Mailed, Angular-scaled, and Round-scaled. The Mailed Ganoid fish (*Tabuliferi*) are the oldest, and are directly allied to the Selachii, out of which they originated. Fossil remains of them, though rare, are found even in the upper Silurian (*Pteraspsis ludensis* of the Ludlow strata). Gigantic species of them—about thirty feet in length—coated with strong bony plates, are found in the Devonian system. But of this legion there now lives only the small order of Sturgeons (*Sturiones*), including the Spade-sturgeons (*Spatularidæ*), and those Sturgeons (*Accipenseridæ*) to which belong, among others, the Huso, which yields isinglass, or sturgeon's sound, and the Caviar-sturgeon, whose eggs we eat in the shape of caviar, etc. Out of the mailed Ganoid fish, the angular and round-scaled ones probably developed as two diverging branches. The Angular-scaled Ganoid fish (*Rhombiferi*)—which can be distinguished at first sight from all other fish by their square or rhombic scales—are at present represented only by a few survivors, namely, the Finny Pike (*Polypterus*) in African rivers (especially the Nile), and by the Bony Pike (*Lepidosteus*) in American rivers. Yet during the palæolithic and the first half of the mesolithic epochs this legion formed the most numerous group of fishes. The third legion, that of Round-scaled Ganoid fish (*Cycliferi*), was no less rich in forms, and lived principally during the Devonian and Coal periods. This legion, of which the Bald Pike (*Amia*), in North American rivers, is the only survivor, was especially important, inas-

much as it includes two important transition groups; on the one hand, the Crossopterygii, which are closely allied to the Dipneusta; on the other hand, the herring Ganoids (Amiades and Leptolepides), out of which the third sub-class of fish, namely, Osseous fish, was developed.

Osseous fish (*Teleostei*) include the greater portion of the fish of the present day. Among these are by far the greater portion of marine fish, and all of our fresh-water fish except the Ganoid fish just mentioned. This class is distinctly proved by numerous fossils to have arisen about the middle of the Mesolithic epoch out of Ganoid fish, and moreover out of the Round-scaled, or Cycliferi. The Thrissopidæ of the Oolitic period (*Thissops, Leptolepis, Tharsis*), which are most closely allied to the herrings of the present day, are probably the oldest of all Osseous fish, and have directly arisen out of Round-scaled Ganoid fish, closely allied to the existing Amia. In the older Osseous fish of the legion called *Physostomi,* as also in the Ganoides, the swimming-bladder throughout life was connected with the throat by a permanent air-passage (a kind of windpipe). This is still the case with all the fish belonging to this legion, namely, with herrings, salmon, carp, shad, eels, etc. However, during the chalk period this air-passage, in some of the Physostomi, became constricted and closed, and the swimming-bladder was thus completely separated from the throat. Hence there arose a second legion of Osseous fish, the *Physoclisti,* which did not attain their actual development until the tertiary epoch, and soon far surpassed the Physostomi in variety. To this legion belong most of the sea-fish of the present day, especially the large families of the Turbot, Tunny, Wrasse, Cod, etc.; further, the

Lock-jaws (Plectognathi), Trunk-fish and Globe-fish, and the Bushy-gills (Lophobranchi), viz. Pipe-fish and Sea-horses. There are, however, only very few Physoclists among our river-fish—for instance, Perch and Sticklebacks; the majority of river-fish are Physostomi.

Midway between genuine Fish and Amphibia is the remarkable class of Mud-fish, or Scaly Sirens (*Dipneusta, Dipnoi,* or *Protopteri*). There now exist only a few representatives of this class, namely, the American Mud-fish (*Lepidosiren paradoxa*) in the region of the river Amazon, and the African Mud-fish (*Protopterus annectens*) in different parts of Africa. A third large Salamander-fish (*Ceratodus Fosteri*) was discovered in 1870, in Australia. During the dry season, that is in summer, these strange animals bury themselves in a nest of leaves in the dry mud, and then breathe air through lungs like the Amphibia. But during the wet season, in winter, they live in rivers and bogs, and breathe water through gills like fish. Externally, they resemble fish of the eel kind, and are like them covered with scales; in many other characteristics also—in their internal structure, their skeleton, extremities, etc.—they resemble Fish more than Amphibia. But in other features they resemble the Amphibia, especially in the formation of their lungs, nose, and heart. There is consequently an endless dispute among zoologists as to whether the Mud-fish are genuine Fish or Amphibia. But in fact, owing to the complete blending of characteristics which they present, they belong neither to the one nor to the other class, and are probably most correctly dealt with as a special class of Vertebrata, forming the transition between Fishes and Amphibians. If the Dipneusta are classed among the Fish

—as is very often done now—the most important characteristics are lost for a clear definition of the class, namely, the typical formation of the fish's heart and the absence of lungs.

Of the still living Dipneusta, Ceratodus possesses a simple single lung (Monopneumones), whereas Protopterus and Lepidosiren have a pair of lungs (Dipneumones). In other respects, also, Ceratodus shows traces of greater age than the two others. All three genera are at any rate very ancient, and the last surviving remains of a group formerly rich in forms. Well-preserved fossil remains of them, especially the very characteristic teeth of Ceratodus, Ctenodus, Dipterus, and kindred genera, have been frequently met with in the Palæozoic formations, in the Devonian and Coal systems, as well as later. These fossil Dipneusta are classed together in the group of Ctenodipterina (Ctenodina and Dipterina). They are directly allied, on the one hand, to the Crossopterygia among the Ganoids, and, on the other, to the Chimæræ (Holocephala) among the Primæval fish. It is probable that, like the still living Ceratodus, they possessed a single lung which developed out of the swimming-bladder of those ancient Ganoids. It was only at a later date that these Monopneumones arose out of the younger Dipneumones, by the single lung dividing into a pair of lung-sacs. These latter then became the ancestors of the Amphibia by changing their many-rayed fins into five-toed creeping feet (see following chapter).

The most important internal change that accompanies the change of the swimming-bladder into the lung, was the division of the ante-chamber of the heart into two ante-

SYSTEMATIC SURVEY

Of the Eight Classes of Vertebrates with regard to the Formation of the Heart and the Limbs.

Heart-formation of the Vertebrates.	*Eight Classes of the Vertebrates.*	*Sub-classes of the Vertebrates.*	*Foot-formation of the Vertebrates.*
I. Main Group: **Tube-hearted** **Leptocardia** Cold-blooded Vertebrates with simple or one-chambered hearts, filled with carbonic blood	1. Skull-less **Acrania**	1. Primæval Vertebrates Provertebrata 2. Amphioxin Cephalochorda	I. Main Group: **Vertebrata adactylia** (*impinnata*) Vertebrates without paired limbs
II. Main Group: **Fish-hearted** **Ichthyocardia** Cold-blooded Vertebrates with two-chambered heart (one ante-chamber and one main-chamber). Blood of the heart carbonic	2. Round-mouths **Cyclostoma**	1. Primæval Skulled animals Procraniota 2. "Bottle gills" Marsipobranchii	
	3. Fishes **Pisces**	1. Primæval fish Selachii 2. Ganoid fish Ganoides 3. Osseous fish Teleostei	II. Main Group: **Vertebrata polydactylia** (*pinnifera*) Originally two pairs of fins, each with a number of fingers or fin-rays
III. Main Group: **Frog-hearted** **Amphicardia** Cold-blooded Vertebrates with three-chambered heart (two ante-chambers and one main-chamber). Blood of the heart mixed	4. Mud-fish **Dipneusta**	1. One lung Monopneumones 2. Two lungs Dipneumones	
	5. Batrachians **Amphibia**	1. Mailed Batrachians Phractamphibia 2. Naked Batrachians Lissamphibia	III. Main Group: **Vertebrata pentadactylia** (*pentanomia*) Originally two pairs of legs, each with three joints (upper-leg, lower-leg, and foot), and with five fingers or toes on every foot
	6. Reptiles **Reptilia**	1. Land reptiles Geosauria 2. Sea reptiles Hydrosauria 3. Tortoises Chelonia 4. Flying reptiles Pterosauria	
IV. Main Group: **Warm Hearts** **Thermocardia** Warm-blooded Vertebrates with four-chambered heart of two divisions (two ante-chambers and two main-chambers). Left side with oxidized blood, right side with carbonic blood	7. Birds **Aves**	1. Lizard-tailed Saururæ 2. Bird-tailed Ornithuræ	
	8. Mammals **Mammalia**	1. Cloacal animals Monotrema 2. Pouched animals Marsupialia 3. Placental animals Placentalia	

chambers. While the fish's heart contained only venous or carbonic blood (Ichthyocardia), there now flows from the lungs arterial or oxidized blood as well; both species of blood mix in the chamber of the heart. By this very important advance of organization the Dipneusta differ widely from their ancestors, the Fish, and form the phylogenetic transition to the Amphibia. The same formation of heart exists also among the Reptiles, so that these three classes might be united under the name of Amphicardia. It is only in the two highest classes of Vertebrates, the Birds and Mammals, that the heart divides into two separate halves; the right half containing venous blood only, the left only arterial blood. These two classes are warm-blooded (Thermocardia, see p. 291).

The heart of the embryo of every one of these higher vertebrates still passes through the same series of changes which the heart of its ancestors slowly passed through during the course of great palæontological periods. Even our human heart has developed in the same way, and thus furnishes a new proof of our derivation from vertebrates, and hence, also, of the fundamental law of biogenesis.

CHAPTER XXV.

HISTORY AND PEDIGREE OF THE AMPHIBIA AND AMNIOTA.

The Five Fingers (Pentadactyly) of the Four Higher Classes (Amphibia and Amniota).—Their Importance for the Decimal System.—Their Origin from the Polydactyl Fish-fins.—Articulation of the Five-toed Extremities in the Three Main Divisions.—Batrachians, or Amphibia.—Mailed Batrachians (Stegocephala and Peromela).—Naked Batrachians (Urodela and Anura).—Main Class of the Amniota, or Amnion Animals.—Formation of the Amnion and the Allantois.—Loss of the Gills.—Protamnion (in the Permian Period).—Separation of the Amniota Tribe into Two Branches (Sauropsida and Mammalia).—Reptiles.—Primary Group of the Tocosaura (Primæval Lizards).—Sea-dragons (Plesiosauria and Ichthyosauria).—Lizards, Serpents, and Crocodiles.—Tortoises (Chelonia).—Flying Dragons (Pterosauria).—Dragons and Lizards (Dinosauria).—Derivation of Birds from Bird-legged Sauria (Ornithoscelides).—The Order of Birds.—Primæval Birds, Toothed Birds, Bushy-tailed or Ostrich-like Birds, Keel-breasted Birds.—Fürbringer's System of Birds and Stereometrical Pedigrees.

THE well-known fact that small causes often lead to incomparably great effects finds its corroboration everywhere in the history of the development of animals. Small, and in themselves insignificant changes of the organization which an animal form has acquired by adaptation to definite new conditions of life, may often prove of great advantage to it in the struggle for existence; and by these changes being transmitted, by inheritance, to a long

series of generations, they may produce the most far-reaching consequences. Very frequently we are unable to perceive the practical advantage of a new arrangement effected by adaptation; but the fact of its being invariably transmitted to large groups of divergent descent, is a sufficient proof of its great phylogenetic significance.

A striking example of this is met with in the history of the development of the Vertebrate tribe, at the historical point which we have just reached. The lower Vertebrates, whose phylogeny we have hitherto been examining, lived in water, breathed through gills and moved about by means of fins; in all Fishes the two pairs of fins are originally many-toed limbs, *polydactyl*. The higher Vertebrates, to which tribe we are about to turn our attention, live for the most part on land, breathe air through lungs, and possess two pairs of limbs which are five-toed, *pentadactyl*. The transition from the aquatic life of fishes to the life on land of the higher Vertebrates (which was commenced by the Dipneusta), in the first place produced, in the Amphibia, most important changes in the organs of breathing and in the circulation of the blood. It, however, at the same time effected changes in the construction of the limbs, which subsequently became of the utmost importance. One of these changes, the reduction in the numerous rays on each fin to the number of *five*, appears in itself insignificant and trifling; and yet an important part of our human civilization is regulated by this accidental process of reduction.

The *Decimal system*, which controls our whole calculation of time, and which has recently also been applied to our systems of coinage, measurements, and weight, owes its origin, as is well known, to the method of calculating

employed by savages, that of counting with the ten fingers of the two hands. The earliest origin of this highly significant number ten lies many millions of years back in the Coal period, perhaps even as far back as the Devonian. In that far-off Palæozoic primæval period the first five-toed Vertebrates, the earliest Amphibia, came into existence; and they transmitted this number of toes to their descendants, by inheritance. The most highly developed of their epigones, Man, has faithfully preserved this number of five, and it has found its most extensive practical application in our present Decimal system.

If the ancient primary Amphibia of the Coal period had inherited from their nearest kinsfolk, the many-fingered Dipneusta, one finger more on each of their extremities, and thus, in place of transmitting five, had transmitted six fingers to their descendants, including man, they would have rendered an inestimable service to humanity. For, accordingly, in place of our Decimal system, we should have the incomparably more practical Duo-decimal system, the fundamental figure of which, *twelve*, can be divided by two, three, four, and six, whereas ten is divisible only by two and five. Further, it would be of advantage in many of the Fine Arts; for instance, in pianoforte-playing, and in many technical pursuits and in surgical operations, six fingers on either hand would be more practical than five. Very little was required, and we might have enjoyed this great advantage. Several ancient Amphibia belonging to the Primary group still possessed six fingers, and in the order of the Sea-dragons (*Halisauria*) this number has been retained by inheritance. Perhaps even the occasional appearance of six fingers in Man (vol. i. p. 182) must be regarded

as a return to the ancient arrangement. However, these are only single exceptions; the possession of five fingers, or pentadactyly, must, upon the whole, have conferred upon us unrecognizable advantages in the struggle for existence. For as far back as the Coal period the number five became constant in the Amphibia, and has established itself by inheritance up to the present day. Although numbers of the higher Vertebrates possess less than five toes on each foot, this is obviously a degeneration from the original number of five.

The origin of the five-toed foot of the Amphibia from the many-toed fin of the Dipneusta and Fishes is, moreover, connected with a series of the most important transformation in the bony structure of the limbs. These are of such importance to the form of body and the mode of life of the four higher classes of Vertebrates, that the latter may be united into one natural phylogenetic main group, as the Pentanomia or Pentadactylia. The Primary group of these is formed by the class of Amphibia; out of these at a later date arose the Amniota, the three classes of Reptiles, Birds, and Mammals. The Amphibia represent the lower and earlier tribe, the Amniota the higher and later line of the Pentanomia.

In all of the Pentanomia, even beginning with the earliest Amphibia, we find originally the characteristic articulation of both pairs of extremities, which our own human organism still possesses, and has retained as an inheritance from those primæval ancestors. In all, the limbs are, in the first place, jointed in three main divisions; the front limb has upper arm, lower arm, and hand; the hind limb has thigh, lower leg, and foot. In all, the skeleton of the first division originally

consists of a large hollow bone, that of the second of two, and that of the third of very numerous small bones, which are again arranged into three groups—the foot-root (Tarsus), the middle-foot (Metatarsus), and the five fingers. The skeleton of the limbs of the Salamander and of the Frog show the same typical formation as that of apes and man. Carl Gegenbaur has shown, in a series of admirable works, how these pentadactyl extremities of the Pentanomia originally developed by differentiation from the polydactyl or many-toed fish-fins of the Dipneusta.

The earliest Amphibia, in whom we ought to be especially interested as the first five-toed ancestors of our tribe, are the Mailed Batrachians of the Coal period, the Stegocephala. Numerous and, for the most part, admirably preserved impressions of them have recently been found in the Carboniferous and Permian systems as well as in the Trias. Credner discovered in the strata round about Plauen, near Dresden (in the lower Permian limestone), more than a thousand of the remarkable Branchiosaurus amblystomus; some of the specimens were in excellent preservation, and Credner was thus enabled very perfectly to restore the anatomy and ontogeny of this Mailed Batrachian. But the common primary form of the Amphibia has even nearer relations than these Microsauria, in the primæval Ganocephala of which the Archegosaurus from the Coal near Saarbrücken, in Alsace, has been known for some time. In the characteristic formation of the teeth, and of the bony plates which cover the salamander-shaped body, these Mailed Batrachians are directly allied to the fossil Dipneusta (*Ctenodina*) and Ganoids (*Crossopterygia*), their probable ancestors. There arose out of these, on the other hand, the gigantic Labyrinth-

toothed animals (*Labyrinthodonta*), which are represented even in the Permian system by Zygosaurus, but at a later period more especially by Mastodonsaurus, Trematosaurus, Capitosaurus, etc. The shape of these formidable rapacious animals seems to have been between that of crocodiles, salamanders, and frogs, but in their internal structure they were more closely related to the two latter, while their solid coat of mail, formed of strong bony plates, resembled that of the crocodiles. These gigantic Mailed Batrachians seem to have become extinct towards the end of the Trias period. No fossil remains from the following periods are known that can with safety be ascribed to the Stegocephala.

While most of the Palæozoic Mailed Batrachians possessed two pairs of five-toed legs, and a more or less developed tail, these parts of the body degenerated in some forms belonging to this group. The remarkable Aistopoda (*Dolichosoma, Ophiderpeton*) assume a serpent-shape, and probably are among the ancestors of the still living blind snakes, or Cæciliæ (Gymnophiona). These are worm-shaped Amphibia, without tail or limbs, and live in the earth of tropical regions like earth-worms. Their ringed skin encloses small, bony scales, the last remains of the solid bony coat of mail which protects most Stegocephala. They may be contrasted with the latter as Peromela. Both orders together form the sub-class of Mailed Batrachians (*Phractamphibia*).

All the other Amphibia known to us belong to the second sub-class, to the Naked Batrachians (Lissamphibia). They probably originated as early as the Palæozoic period, although fossil remains of them are first found in the Chalk and Tertiary epochs. They are distinguished from Mailed

SYSTEMATIC SURVEY

Of the Legions and Orders of the Batrachians, or Amphibia.

Sub-classes.	*Legions.*	*Orders.*	*Name of Genus as Example.*
I. First Sub-class of the Amphibia Mailed Batrachians **Phractamphibia** Skin coated with bony plates	First Legion: **Scaled Batrachians** **Stegocephala** (*Archamphibia*) Like lizards, tailed, mostly with weak limbs	1. Ganocephala. *Archegosauria.*	Archegosaurus. Eryops.
		2. Labyrinthodonta. *Mastodonsauria.*	Labyrinthodon. Trematosaurus.
		3. Lepospondyla. *Microsauria.*	Branchiosaurus. Ceraterpeton.
	Second Legion: **Snake-like Batrachians** **Peromela** (*Pseudophidia*) Like snakes, footless and tail-less	4. Procœciliæ. *Aistopoda.*	Dolichosoma. Ophiderpeton.
		5. Cœciliæ. *Gymnophiona.*	Epicrium. Siphonops.
II. Second Sub-class of the Amphibia Naked Batrachians **Lissamphibia** Skin naked and smooth, without bony plates	Third Legion: **Tailed Batrachians** **Urodela** (*Caudata*) Like salamanders, with long tail and weak limbs	6. Fish-Batrachians. *Perennibranchia.*	Proteus. Siren.
		7. Derotrema. *Cryptobranchia.*	Menopoma. Amphiuma.
		8. Salamanders. *Caducibranchia.*	Triton. Salamandra.
	Fourth Legion: **Frog-like Batrachians** **Anura** (*Batrachia* or *Ecaudata*) Like frogs, tail-less, with strong limbs (the larvæ are tailed tadpoles)	9. Tongue-less toad. *Aglossa.*	Pipa. Dactylethra.
		10. Toads. *Bufonacea.*	Bufo. Phryniscus.
		11. Tree-toads. *Callulacea.*	Callula. Hylaplesia.
		12. Frogs. *Ranacea.*	Rana. Bombinator.
		13. Tree-frog. *Hylacea.*	Hyla. Hylodes.

Batrachians by possessing a naked, smooth, slimy skin, entirely without scales or coat of mail. By degeneration and loss of the bony covering of mail, the Lissamphibia developed out of a branch of the Phractamphibia. The Lissamphibia are usually divided into two orders—Tailed (*Urodela*) and Tail-less (*Anura*). The Tailed Lissamphibia (*Urodela*) are again divided into three groups, which, in their individual development, still repeat most distinctly the historical course of development of the whole sub-class. The earliest forms are the Gilled Batrachians (*Perennibranchia*), which possess throughout life the original primary form of the Naked Batrachians, and retain the long tail and the water-breathing gills. They stand nearest to the Stegocephala and Dipneusta, from which, however, they differ externally by the absence of the coat of mail. Most of the Gilled Batrachians live in North America; among others of the class, Siren and the already mentioned Axolotl (Siredon, see vol. i. p. 259). In Europe this order is represented by only one form, the celebrated "Olm" (Proteus anguineus), which inhabits the grotto of Adelsberg and other caves in Carinthia, and which, from living in the dark, has acquired rudimentary eyes that can no longer see (compare vol. i. pp. 14, 325). Out of the Gilled Batrachians, by loss of the external gills, the order of the Derotrema were developed (the *Cryptobranchia*). This order contains the largest of all living Amphibia, the giant-salamander of Japan (*Cryptobranchus*—over a metre in length). Out of these again arose the Salamanders, to which belongs our black and yellow spotted land-salamander (*Salamandra maculosa*), and our nimble aquatic salamanders (*Tritons*). These latter entirely lose the gills, which their larvæ possess

in early youth. But sometimes the Tritons retain the gills, and thus remain at the stage of Gilled Batrachians, that is to say, if compelled to remain always in water (see vol. i. p. 260). The third order, the Tail-less or Frog-like Batrachians (Anura or Batrachia), during their metamorphosis, not only lose their gills, with which in early life (as so-called tadpoles) they breathe in water, but the tail with which they swim about. In their ontogeny, therefore, they pass through the course of development of the whole sub-class, being at first Gilled Batrachians, then Derotrema, then Salamanders, and lastly Frog-like Batrachians. The inference from this evidently is that the Frog-like Batrachians have developed out of Gilled Batrachians. The wonderful metamorphosis of the well-known tadpoles into frogs, which we can ourselves observe any spring within a few weeks, thus repeats to us, according to the biogenetic law, an historical process which is one of the most important in the whole history and pedigree of the Vertebrate animals.

In passing from the Amphibia to the next class of Vertebrata, namely, Reptiles, we observe a very considerable advance in the progress of organization. All the double-nostriled animals (Amphirhina) up to this time considered, viz. Fish, Dipneusta, and Amphibia, agree in a number of important characteristics, which essentially distinguish them from the three remaining classes of Vertebrata—Reptiles, Birds, and Mammals. During the embryological development of these latter, a peculiarly delicate covering, the *first fœtal membrane*, or *amnion*, which grows out from the navel, is formed round the embryo; this membrane is filled with the amnion-liquid, and encloses the embryo or germ in the form of a bladder. On account of this very important and

characteristic formation, we may comprise the three most highly developed classes of Vertebrata under the term Amnion-animals (*Amniota*). In the three classes of double-nostriled animals which we have just considered, the amnion is wanting (as is the case in all lower Vertebrate animals, single-nostriled and skull-less animals), and hence they may be opposed to the others as Amnion-less animals (*Anamnia*).

The formation of the water-cushion, or amnion, which distinguishes reptiles, birds, and mammals from all other Vertebrata, is evidently a very important process in their ontogeny, and in the phylogeny which corresponds with it. It coincides with a series of other processes, which essentially determine the higher development of Amnionate animals. The first of these important processes is the *total loss of gills,* for which reason the Amniota, under the name of *Gill-less animals* (Ebranchiata), were formerly opposed to all other Vertebrate animals which breathe through gills (Branchiata). In all the Vertebrata already discussed we found that they either always breathed through gills, or at least did so in early life, as in the case of Frogs and Salamanders. On the other hand, we never meet with a Reptile, Bird, or Mammal which at any period of its actual life breathes through gills, and the gill-arches and openings which do exist in the embryos are, during the course of their ontogeny, changed into entirely different structures, viz. into parts of the jaw-apparatus and the organ of hearing (see vol. i. p. 353). All Amnionate animals have a so-called cochlea in the organ of hearing, and a "round window" corresponding with it. These parts are wanting in the Amnion-less animals; moreover, in them the skull of the embryo

lies in a straight line with the axis of the vertebral column. In Amnionate animals, the base of the skull is bent in on the abdominal side, so that the head sinks upon the breast (see Plate III., Fig. *C, D, G, H*). The organs of tears at the side of the eye also first develop in the Amniota; and, finally, all Amniota possess an Allantois, an organ of nutrition for the embryo, which has developed out of the urinary bladder of the Amphibians.

The question now is, When did this important advance take place in the course of the organic history of the earth? When did the common ancestor of all Amniota develop out of a branch of the Non-Amniota, to wit, out of a branch of the Amphibia?

To this question the fossil remains of Vertebrata do not give us a very definite, but still they do give an approximate, answer. The earliest fossil remains of Vertebrata which we can with safety refer to Amniota, are skeletons of some Reptiles from the Permian system (Proterosaurus, Parasaurus, Sphenosaurus, and a few others). These reptiles appear to belong to the earliest Amnion-animals, and to be closely akin to our common lizards. All the other fossil remains we as yet know of Amnion-animals belong to the Secondary, Tertiary, and Quaternary periods. Of course it is the skeleton alone that is known to us of those most ancient Permian lizards. And as we know nothing whatever of the distinguishing characteristics of their soft parts, it is quite possible that they were still non-Amnionate animals, which stood closer to the Amphibians than to the Reptiles; they may even possibly have been transition-forms between the two classes. On the other hand, undoubted fossil remains of Amniota have been found as early as the

Trias, and, indeed, of very different groups. It is probable, therefore, that a more varied, phylogenetic development and distribution of the main class of Amniota took place in the Trias period, towards the beginning of the Mesolithic period; whereas the earlier primary forms lived in the Permian period, perhaps even as early as the Coal period. As we have already seen, this very period is evidently one of the most important turning-points in the organic history of the earth. The palæolithic fern forests were then being replaced by the pine forests of the Trias period; important transformations then took place in many of the classes of the Invertebrata. Articulated marine lilies (Neocrinidæ) developed out of the plated ones (Palacrinidæ). The Metechinidæ, or Sea-urchins, with only twenty rows of plates, took the place of the palæolithic Palechinidæ, those with more than twenty rows of plates. The Cystoidea, Blastoidea, Trilobita, and other characteristic groups of Invertebrata of the Primary period, became extinct. It is no wonder that transforming conditions of adaptation powerfully influenced the Vertebrate tribes also in the beginning of the Trias period, and gave rise to a rich development of forms among the Amniota.

Other zoologists, on the contrary—Huxley more especially—are of the opinion that a multifarious development of the Reptile class took place as early as the Permian period, and that consequently their first origin must be assigned to an even earlier period. And, indeed, there are many reasons which favour this supposition. However, all the remains of Reptiles that were formerly believed to have been found in the Coal, or even in the Devonian, system, have been proved either not to be remains of Reptiles at all, or to

belong to a much more recent date (for the most part to the Trias); for instance, the *Telerpeton elginense* from the Trias.

The common hypothetical primary form of all Amniota, which we may call Protamnion, and which was possibly nearly related to the Proterosaurus, very probably, upon the whole, stood midway between salamanders and lizards as regards external form of body and internal organization. Its elongated body possessed a short neck, long tail, and four short five-toed legs. Its skin was scaled or covered with small bony plates, as in the case of its primæval ancestors, the earliest Stegocephala (Microsauria). Its descendants divided, at an early period, into two different lines, one of which became the common primary form of the Sauropsida, Reptiles, and Birds; the other the primary form of Mammals.

Of all the three classes of Amniota, the Reptiles (*Reptilia* or *Pholidota*, also called *Sauria* in the widest sense) remain at the lowest stage of development, and differ least from their ancestors, the Amphibia. Hence they were formerly universally included among them, although their whole organization is much more like that of Birds than of Amphibia. There now exist only four orders of Reptiles, namely, Lizards, Serpents, Crocodiles, and Tortoises. They, however, form but a poor remnant of the exceedingly various and highly developed host of Reptiles which lived during the Mesolithic or Secondary period, and predominated over all other Vertebrata. The immense development of Reptiles during the Secondary epoch is so characteristic, that we might as well name it after those animals as after the Gymnosperms (see p. 312). Of the forty families, given on

the accompanying table, twenty-two belong exclusively to the Secondary period, and likewise five of the nine orders. These mesolithic groups are marked with an asterisk. With the single exception of the Serpents—which appeared first in the Tertiary—all the different orders are found fossil in the Jurassic and Trias periods; the earliest forms even in the Permian system.

The grand palæontological discoveries of the two last decades, and, above all, those of Cope and Marsh, the two unwearied North American palæontologists, have made us acquainted with a fauna of astonishing wealth of forms among the Mesolithic Reptiles. For the most part they appear to be independent orders and families of the Reptile tribe of very peculiar development ("specialized types"); the rest are very valuable phylogenetic connecting links, which unite this multifarious class, on the one hand, directly with their primary group, the Phractamphibia, and, on the other, explain their blood-relationship with Birds and Mammals, the two highest classes of Vertebrates which have developed out of different branches of Reptiles. Many of these extinct Reptiles of the Secondary period possessed extraordinary forms, and surpassed in peculiarity of formation any of the fantastic creatures of fable-land which the imagination of a "Breughel of Hades"—or, in our day, an Arnold Bœcklin—described as the inhabitants of the lower regions. Among them were the largest land-animals that have ever existed; many of these "dragons" were over fifty feet in length, some over a hundred feet. The largest (Dinosauria) were plant-eaters, with a minute little brain, and must have been extremely stupid, colossal creatures. They possessed a mighty armour of plates or scales; many also spikes and

spurs, which protected them against the attacks of the colossal flesh-eaters, which were armed with terrible jaws.

At present it is impossible to obtain a clear insight into the complicated relationships between these wonderful Reptile forms; the less so as every year the number of them is considerably increased by new and surprising discoveries. And the opinions of those best acquainted with the subject still differ widely as regards the mutual phylogenetic connections between these forms. If we wish to class the nine main groups given on p. 312, and which are hypothetically arranged in the provisional pedigree on p. 313, in a few large main divisions, the four following sub-classes of Reptiles might be distinguished: 1. *Geosauria*, Land Reptiles (Tocosauria, Lizards, Serpents, Theriosauria, and Dinosauria); 2. *Hydrosauria*, Sea Reptiles (Halisauria and Crocodiles); 3. *Chelonia*, Tortoises; and 4. *Pterosauria*, Flying Reptiles.

The first order of Reptiles, that of the *Primary Reptiles*, or *Tocosauria*, comprises the earliest and lowest forms both of the Reptilia as well as of the Amniota generally. We, therefore, first of all subdivide this group into three families. The first family is formed by the hypothetical Primæval Amniota (Protamniota), which, for reasons already stated, we have to regard as the common primary forms of all Amnion-animals. Among these were the remarkable transition-forms between certain salamander-like Amphibia (Stegocephala), and those most ancient lizard-like Reptiles which first acquired the amnion and allantois. These Protamniota existed at latest during the Permian period, perhaps even as early as the preceding Coal period. They form the common root, to which, on the one hand, the earliest

primary forms of the Mammalia (Promammalia) have to be traced, and, on the other, to which the Birds and true Reptiles (Proreptilia) have to be traced. Among these latter we may include the remarkable mailed Bird-lizard which was found in the Keuper near Stuttgart (Aëtosaurus ferratus). It presents the united characteristics of the most different orders of Reptiles and at the same time of Birds. The Primæval Lizards, or Proterosauria, were probably very closely allied to the Proreptilia. These Proterosauria are the earliest fossil Reptiles which we as yet know of, and are met with in the Permian system (*Proterosaurus, Parasaurus, Sphenosaurus*, etc.). The earliest known remains of these important Proterosauria (which were very like our common lizards, and especially the Monitors) is the Thuringian *Proterosaurus Speneri*, discovered in the copper-slates near Eisenach as early as 1710, and first described by the Berlin physician Spener.

Out of the Tocosauria—which are specially important as the common primary group of all Amniota—there probably arose during the Permian period a number of diverging branches of Reptiles, which thereupon, during the subsequent Trias period, attained to a much higher development, and to their full development during the Jura period. Owing to the present state of our knowledge, we can form only a provisional hypothesis as regards their relationships to one another; the simplest outlines of their pedigree are given on p. 313. The most conservative and least changed order is probably that of the true Lizards (*Autosauria* or *Lacertilia*). The Serpents (*Ophidia*) developed later out of a branch of these. Other branches of the Reptile tribe, which arose directly or indirectly out of the Tocosauria, are

the Crocodiles and Tortoises. Two different groups of Reptiles learned to fly, and became inhabitants of the air—on the one hand the Flying-lizards (Pterosauria), and on the other the Birds; the latter are derived from the Ornithoscelides, a branch of the Dinosauria. The primary forms of the Mammalia arose out of a very different group, the Theriosauria. Lastly, a very peculiar group is formed by the Sea-dragons (*Halisauria*), their position among the Reptiles being still very doubtful.

The Vertebrates, which we class together under the name of Sea-dragons (*Halisauria* or *Enaliosauria*), are long since extinct, and were so as early as the Chalk period. These formidable animals of prey inhabited the Mesolithic oceans in immense numbers, and were of the strangest forms, sometimes of from thirty to forty feet in length. Very many and excellently preserved fossil remains, both of the entire sea-dragons as well as of separate portions of them, have made us well acquainted with the structure of their bodies. They are now usually classed among the Reptiles, but some anatomists place them in a much lower rank and in direct connection with the Fishes. Gegenbaur's recent investigations, which above all others place the important formation of the limbs in the right light, appear to lead to the astounding conclusion that the Sea-dragons form an isolated group, differing widely both from the Reptiles and Amphibians as well as from the Fishes. The formation of the skeleton of their four legs, which have become transformed into short, broad paddling fins (like those of Fish and Whales), seems to prove that the Halisauria branched off from the Vertebrate tribes earlier than the Amphibia. For the Amphibia, as well as

the three higher classes of Vertebrata, are all derived from one common primary form, which possessed on each leg but *five* toes or fingers. The Sea-dragons, on the other hand, possess more than five fingers, like the Primæval Fish (these fingers are either distinctly developed, or in a rudimentary condition, as parts of the skeleton of the foot). However, this excess of toes may perhaps have arisen secondarily out of the pentadactyl primary form by degeneration. The Halisauria unquestionably breathed through lungs, like the similar Porpoises and Dipneusta, notwithstanding that they always swam about in the sea. They did not develop further into higher Vertebrates, but constitute an extinct side-line.

The more accurately known Sea-dragons are divided into our families that differ pretty widely from one another—the Primæval dragons, Serpent-dragons, Fish-dragons, and the Beaked dragons. The Primæval dragons (*Simosauria*) are the oldest Sea-dragons, and lived only during the Trias period. The skeletons of many different genera of them are met with in the German limestone known as "Muschelkalk." They seem upon the whole to have been very like the Plesiosauria, and are, consequently, sometimes united with them into one order as Sauropterygia. The Serpent-dragons (*Plesiosauria*) lived in the oolitic and chalk periods together with the Ichthyosauria. They were characterized by an uncommonly long thin neck, which was frequently longer than the whole body, and carried a small head with a short snout. When their arched neck was raised they must have looked very like a swan; but in place of wings and legs they had two pairs of short, flat, oval paddling fins.

The body of the Fish-dragons (*Ichthyosauria*) was of an

entirely different form; these animals may be opposed to the two preceding orders under the name of Fish-finners (*Ichthyopterygia*). They possessed a very long extended body, like a fish, and a heavy head with an elongated, flat snout, but a very short neck. Externally, they were probably very like porpoises. Their tail was very long, whereas it was very short in the members of the preceding orders. Also both pairs of paddling fins are broader, and show a very different structure from that met with in the other two orders. The true Ichthyosauria have fearful teeth in their jaws; these teeth have been lost in the North-American Beaked dragons (*Sauranodontia*). Perhaps the Fish-dragons and the Serpent-dragons developed as two diverging branches out of the Primæval dragons. But it is also possible that the Simosauria gave rise to the Plesiosauria only, while the Ichthyosauria branched off from the common root much lower down. The Sauranodontia are derived from the Ichthyosauria.

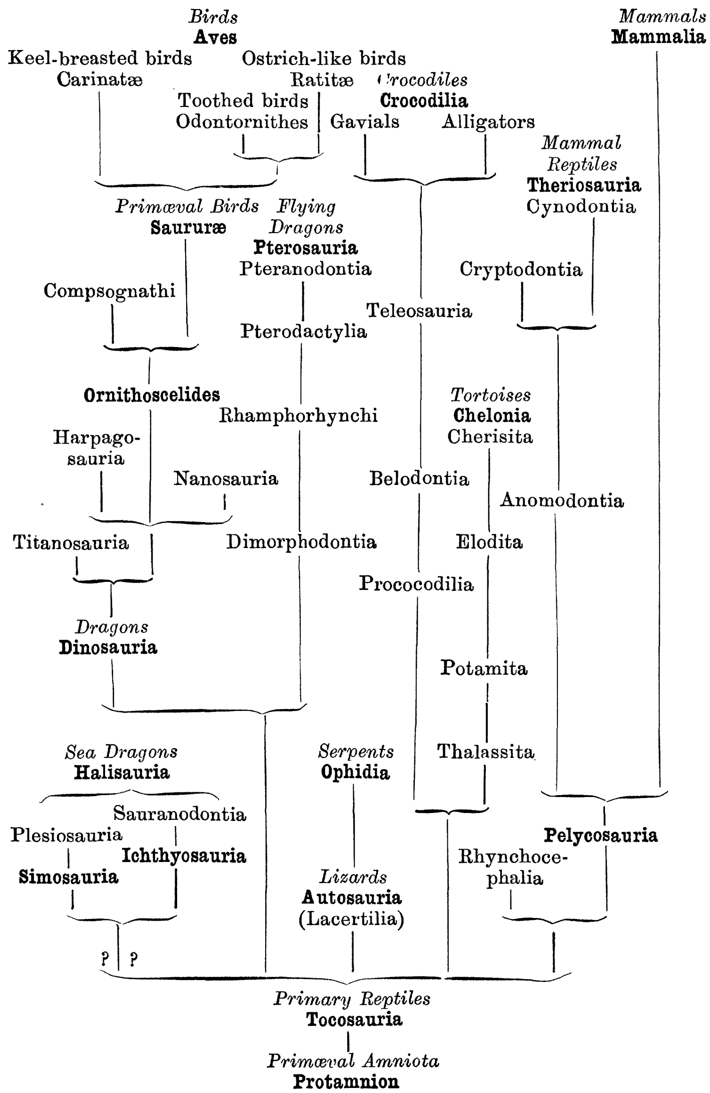
Of the four orders of Reptiles now existing, and which have alone represented the class since the beginning of the Tertiary period, that of Lizards (*Autosauria* or *Lacertilia*) is obviously most closely related to the extinct Primary Reptiles, and especially through the already mentioned Monitors. The class of Serpents (*Ophidia*) developed out of a branch of the order of Lizards, by degeneration of the four legs and a loosening of the jaw-skeleton. The giant Serpents still possess the remains of the degenerated hind legs; they originated probably towards the beginning of the Tertiary period. At all events, fossil serpents have as yet been met with only from the Tertiary deposits. Crocodiles (*Crocodilia*) existed much earlier; the

SYSTEMATIC SURVEY

Of the Orders and Families of the Reptiles.

(Those groups marked with * became extinct during the Secondary Period.)

Orders of the Reptiles.	*Families of the Reptiles.*	*Families of the Reptiles.*	*A Generic Name by way of Example.*
I. Primary Reptiles Tocosauria	1. Primæval amniota	1. Protamniota.	* Protamnion.
	2. Primæval reptiles	2. Proreptilia.	* Aëtosaurus.
II. Lizards Autosauria	3. Primæval lizards	3. Proterosauria.	* Proterosaurus.
	4. Geckos	4. Ascalabotæ.	Platydactylus.
	5. Monitors	5. Monitores.	Monitor.
	6. Lacertina	6. Lacertina.	Lacerta.
	7. Chalcidians	7. Chalcidia.	Zonurus.
	8. Scincoida	8. Scincoida.	Anguis.
	9. Mosasauria	9. Mosasauria.	* Mosasaurus.
	10. Ringed lizards	10. Glyptoderma.	Amphisbæna.
	11. Chameleons	11. Vermilingues.	Chamæleo.
III. Serpents Ophidia	12. Adders	12. Aglyphodonta.	Coluber.
	13. Tree-serpents	13. Opisthoghypha.	Dipsas.
	14. Water-vipers	14. Proteroghypha.	Hydrophis.
	15. Vipers	15. Solenoglypha.	Vipera.
	16. Worm-serpents	16. Opoterodonta.	Typhlops.
IV. Crocodiles Crocodilia	17. Thecodonts	17. Thecodontia.	* Belodon.
	18. Teleosauria	18. Teleosauria.	* Teleosaurus.
	19. Gavials	19. Gaviales.	Gavialis.
	20. Alligators	20. Alligatores.	Alligator.
V. Tortoises Chelonia	21. Sea-tortoises	21. Thalassita.	Chelone.
	22. River-tortoises	22. Potamita.	Trionyx.
	23. Marsh-tortoises	23. Elodita.	Emys.
	24. Land-tortoises	24. Chersita.	Testudo.
VI. Sea Dragons Halisauria	25. Primæval dragons	25. Simosauria.	* Simosaurus.
	26. Serpent-dragons	26. Plesiosauria.	* Plesiosaurus.
	27. Fish-dragons	27. Ichthyosauria.	* Ichthyosaurus.
	28. Beaked dragons	28. Sauranodontia.	* Sauranodon.
VII. Flying Dragons * Pterosauria	29. Long-tailed	29. Dimorphodontia.	* Dimorphodon.
	30. Flying-lizards	30. Rhamphorhynchi.	* Rhamphorhynchus.
	31. Short-tailed	31. Pterodactyli.	* Pterodactylus.
	32. Flying-lizards	32. Pteranodontia.	* Pteranodon.
VIII. Dragons * Dinosauria	33. Dwarf-dragons	33. Nanosauria.	* Nanosaurus.
	34. Giant-dragons	34. Harpagosauria.	* Megalosaurus.
	35. Elephantine dragons	35. Titanosauria.	* Iguanodon.
	36. Bird-like lizards	36. Ornithoscelides.	* Compsognathus.
IX. Mammal Reptiles Theriosauria	37. Pelycosauria	37. Pelycosauria.	* Pelycosaurus.
	38. Beaked lizards	38. Rhynchocephalia.	* Rhynchocephalus.
	39. Dog-toothed	39. Cynodontia.	* Dicynodon.
	40. Toothless	40. Cryptodonia.	* Udenodon.


Birds
Aves
Keel-breasted birds
Carinatæ
Ostrich-like birds
Ratitæ
Toothed birds
Odontornithes
Crocodiles
Crocodilia
Gavials
Alligators
Mammals
Mammalia
Mammal Reptiles
Theriosauria
Cynodontia
Primæval Birds
Saururæ
Flying Dragons
Pterosauria
Pteranodontia
Cryptodontia
Compsognathi
Teleosauria
Pterodactylia
Ornithoscelides
Rhamphorhynchi
Tortoises
Chelonia
Cherisita
Harpago-sauria
Nanosauria
Belodontia
Anomodontia
Titanosauria
Dimorphodontia
Elodita
Procrocodilia
Dragons
Dinosauria
Potamita
Sea Dragons
Halisauria
Serpents
Ophidia
Thalassita
Sauranodontia
Plesiosauria
Ichthyosauria
Simosauria
Pelycosauria
Rhynchoce-phalia
Lizards
Autosauria
(Lacertilia)
?
?
Primary Reptiles
Tocosauria
Primæval Amniota
Protamnion

oldest forms of this class, the Thecodontia or Belodontia, are found fossil in large quantities as early as the Jura; the still living alligators and gavials, on the other hand, are first met with fossil in the Chalk and Tertiary deposits. The earliest forms of the Crocodiles are directly allied to a branch of the fossil Tocosauria; their phylogeny can be distinctly followed step by step.

The most isolated of the four living orders of Reptiles, is the remarkable group of Tortoises (*Chelonia*). Fossils of these strange animals are first met with in the Jura. In some characteristics they are allied to Amphibia, in others to Crocodiles, and by certain peculiarities even to Birds, so that their true position in the pedigree of Reptiles is uncertain; and it probably lies far down at the root. The extraordinary resemblance of their embryos to birds, manifested even at the later stages of the ontogenesis, is exceedingly striking (compare Plates II. and III.). Of the four subdivisions of Tortoises, the oldest are the Sea-tortoises (*Thalassita*). Out of these were subsequently developed the River-tortoises (*Potamita*), and out of these again the Marsh-tortoises (*Elodita*). Lastly, at a much later date, not till the Tertiary, appear the Land-tortoises (*Chersita*). The development of the characteristic plates of bone in the skin advances gradually from the first to the last subdivision, and so likewise does the peculiar transformation of the head and legs.

Of the five interesting orders of extinct Reptiles, the most abnormal and most curious forms are the Flying-dragons, or Flying-reptiles (*Pterosauria*); flying-lizards in which the extremely elongated fifth finger of the hand served to support an enormous flying-membrane. They

probably flew about, in the secondary period, much in the same way as the bats of the present day. The smallest flying-lizards were about the size of a sparrow; the largest, however, with a breadth of wing of more than sixteen feet, exceeded the largest of our living flying-birds in stretch of wing (condor and albatross). They were actual flying-dragons with terrible jaws. The earlier Pterosauria (*Dimorphodontia* and *Rhamphorhynchi*) possessed a long tail; in the later ones (Pterodactylia and Pteranodontia) it had degenerated; the colossal Pteranodontia had likewise lost their teeth; an interesting parallel with the Birds. Fossil remains of them, especially of the long-tailed Rhamphorhynchi and the short-tailed Pterodactylia, are found in quantities in all the strata of the Jura and Chalk periods, but in these only.

Not less remarkable and characteristic of the Mesolithic epoch, was the group of Dragons (*Dinosauria*). These colossal reptiles, which attained a length of from fifty to eighty feet, and a height of between twenty and thirty feet, are the largest inhabitants of the land which have ever existed on our globe. They lived exclusively in the Secondary period, beginning in the Lower Trias, and cease in the Upper Chalk. Most of their remains are found in the Jurassic and in the Lower Cretaceous systems, especially in the Wealden formations. The majority of them were fearful beasts of prey (the Megalosaurus from twenty to thirty feet in length, Pelorosaurus between forty and sixty feet). Ignuanodon, however, and many others lived on vegetable food, and probably played a part in the forests of the Chalk period similar to that of the unwieldy but smaller elephants, hippopotami, and rhinoceroses of the present day. Among

the colossal plant-eaters is the largest of all known land-animals, the enormous Atlantosaurus, which attained a length of a hundred and fifteen feet, with a height of thirty feet; it may have consumed a whole tree for breakfast. Its vertebræ were over a foot in diameter. This astounding monster was discovered in 1877, in the chalk deposits of Colorado in North America, by the eminent palæontologist, Marsh, to whom we also owe the discovery of very many other exceedingly interesting fossil vertebrata; all of these are preserved among the unrivalled palæontological collection of Yale College in New Haven (Connecticut). But beside these giants, the Dinosauria include also many smaller forms, down to the size of a cat and a lizard. Morphologically they are interesting, chiefly on account of the construction of the skeleton of their limbs, especially the girdles of the shoulder and pelvis. For in one branch of the Dinosauria this gradually leads over to the characteristic formation of these parts in Birds, for which reason Huxley has given this branch the name of *Ornithoscelides, i.e.* bird-legged. In a narrow sense this name might be applied to the curious kangaroo-like Compsognathus, from the Jura of Solenhofen, which leads directly over to the Birds.

In the same way as the Dinosauria form a transition group from the Primæval Amniota to Birds, the Mammal Reptiles (*Theriosauria* or *Theriomorpha*) form the transition group to the Mammalia. The distinguished American palæontologist, Cope—to whom we are likewise indebted for many very important fossil Vertebrata—has recently shown that these Theriosauria (mostly from the Trias), by a long series of intermediate forms, lead over from the Tocosauria to the Mammalia, and in fact to the Monotrema.

This is evident from the structure of their limbs, especially of the girdles of the shoulder and pelvis. The *Pelycosauria* are the earliest Theriosauria; although they were inhabitants of the land, they still possess a simple notochord in place of the articulated vertebral column. These are subsequently followed by the *Anomodontia*, some of which had large dog-like teeth (*Cynodontia*), and some had lost their teeth entirely (*Cryptodontia*). The primary forms of Mammals (Promammalia) probably developed out of the group of Theriosauria during the Trias period.

The class of Birds (*Aves*), as already remarked, is so closely allied to Reptiles in internal structure and by embryonic development, that they undoubtedly originated out of a branch of this class. Even a glance at Plates II. and III. will show that the embryos of birds, at a time when they already essentially differ from the embryos of Mammals, are still scarcely distinguishable from those of Tortoises and other Reptiles. The cleavage of the yolk is partial in the case of Birds and Reptiles: in Mammals it is total. The red blood-cells of the former possess a kernel, those of the latter do not. The hair of Mammals develops in closed follicles in the skin, but the feathers of Birds and also the scales of Reptiles develop on papillæ on the skin. The separate pieces of the lower jaw of the latter remain distinct, whilst in Mammals they are fused as one bone. The Mammals do not possess the quadrate bone of the Birds and Reptiles. Whereas in Mammals (as in the case of Amphibia) the connection between the skull and the first neck-vertebra is formed by two knobbed joints, or condyles, in Birds and Reptiles these have become united into a single condyle. Hence Huxley very justly unites the two last

classes into one group as *Sauropsida,* and contrasts them with the Mammals.

The derivation of Birds from Reptiles, in any case, first took place in the Trias. The oldest fossil remains of birds are found in the Upper Jura (*Archæopteryx*). But there existed, even in the Trias period, various Dinosaurians, which in many respects seem to form the transition from the Tocosauria to the primary ancestors of Birds, the hypothetical Protornithes. The already mentioned Compsognathus from the Jura of Solenhofen is one of these remarkable transition-forms.

The great majority of Birds—in spite of all the variety in the colouring of their beautiful feathery dress, and in the formation of their beaks and feet, are, like the class of insects, of an exceedingly uniform organization. The bird-form has adapted itself on all sides to the external conditions of existence, without having thereby in any way essentially deviated from the strict hereditary type of its characteristic structure.

The so-called "orders" of Birds, therefore, differ in a much lesser degree than the various orders of Reptiles or Mammals. Upon the whole, we distinguish only *four* orders of Birds: (1) the Primæval Birds (*Saururæ*); (2) the Toothed Birds (*Odontornithes*); (3) the Ostrich-like Birds (*Ratitæ*); and (4) the Keel-breasted Birds (*Carinatæ*). The three latter might be classed in the subdivision of Bird-tailed (Ornithuræ), while the first order alone would represent the earlier sub-class of the Lizard-tailed birds (Saururæ: see my "Gen. Morph." under *Saururæ,* 1866, vol. ii.).

The first order, the Primæval Birds (*Saururæ*), are, as

yet, known only through a single fossil species, and that imperfectly preserved, which, however, in being the oldest fossil bird and also very peculiar, is of great importance. This fossil is the Primæval Griffin, or *Archæopteryx lithographica,* of which as yet only two specimens have been found in the lithographic slate at Solenhofen, in the Upper Jura system of Bavaria; the first specimen was found in 1861, the second in 1877. It may be regarded as a near relative of the common primary form of all birds, the hypothetical *Protornis.* This remarkable bird seems, on the whole, to have been of the size and form of a large raven, as is evident from the legs, which are in a good state of preservation; head and breast, unfortunately, are wanting. A fragment of the beak contains small teeth. The formation of the wings differs somewhat from that of other birds, but that of the tail still more so. In all other birds the tail is very short, and composed of but few short vertebræ; the last of these have grown together into a thin bony plate standing perpendicularly, upon which the rudder-feathers of the tail are attached in the form of a fan. The Archæopteryx, however, has a long tail like a lizard, composed of numerous (twenty) long thin vertebræ, and on every vertebra are attached the strong rudder-feathers in pairs, so that the whole tail appears regularly feathered. This same formation of the tail part of the vertebral column occurs transiently in the embryos of other birds, so that the tail of the Archæopteryx evidently represents the original form of bird-tail inherited from reptiles. Large numbers of similar birds with lizard-tails probably lived during the middle of the Secondary period; accident has as yet, however, revealed only this one species.

A second and likewise extinct order of Birds is formed by the remarkable Toothed Birds (*Odontornithes*), which Marsh has discovered in the chalk formations of North America. They already possessed the short fan-tail of the ordinary keel-breasted birds, but still had numerous teeth in their beak, like the primæval birds. Some of them were very large. Hesperornis, which resembled a swimming carnivorous ostrich, attained a length of over two metres. This form is closely allied to the following order of the Ratitæ, whereas other Toothed birds (Ichthyornis) show closer affinity with the Carinatæ (Swimming-birds).

The third order, the Ostrich-like Birds (*Ratitæ*), also called Running Birds (*Cursores*), are at present represented only by a few living species, by the two-toed African ostrich, the three-toed American and Australian ostrich, by the Indian cassowary, and the four-toed Riwi or Apteryx of New Zealand. The extinct giant-birds of Madagascar (Æpyornis) and the New Zealand Dinornis, which were much larger than the still living ostriches, also belong to this group. The Birds of the ostrich kind—by giving up the habit of flying, by the degeneration of the muscles for flying resulting from this, and of the breast-bone which serves as their support, and by the corresponding stronger development of the hinder legs for running—have probably arisen out of a branch of the Keel-breasted birds. They accordingly form a polyphyletic group. A less probable supposition, advocated by Huxley more especially, is that the Ratitæ are not derived from Flying-birds, but that they probably are the nearest relatives of the Dinosauria, especially of the Compsognathus; in this case they would be more closely allied to the Primæval birds than the Keel-breasted birds.

The Keel-breasted Birds (*Carinatæ*) include all our present living birds, with the exception of the ostrich kind, or Ratitæ. They probably developed during the second half of the Secondary period, namely, in the Jura and Chalk period, out of the feather-tailed Birds, by the hinder tail-vertebræ growing together, and the tail becoming shortened. Only a very few remains of them are known from the Secondary period, and these, moreover, only out of the last section of it, namely, from the Chalk. These remains belong to several different kinds of swimming-birds and wading-birds. All the other fossil remains of birds as yet known have been found in the Tertiary strata. As all these Keel-breasted birds are closely related to one another, and appear connected in various different ways, it is a very puzzling task to trace the pedigree of the tribe.

Max Fürbringer, in his great work, "Investigations on the Morphology and Systematic Arrangement of Birds" (1888), has recently and with the greatest skill undertaken to solve phylogenetically the difficult problem of the complicated relationships among the whole class of Birds. He has come to the conclusion—after extremely careful and comprehensive investigations—that the whole class is monophyletic, and derived from an ancient group of primæval birds, probably belonging to the Trias or to the Permian epoch. The *Archæopteryx lithographica* from the Jura must be regarded as the only known example of this primary group. The orders of the Toothed Birds and the Ostrich-like Birds are, according to Fürbringer, both polyphyletic, and are derived from different classes of Flying-birds, or Carinata. The latter he divides into four orders—*Pelargornithes* (the birds of prey and most swimming-

SYSTEMATIC SURVEY

Of the Orders and Families of Birds.

Orders of Birds.	*Character of the Orders.*	*Families of Birds.*	*A Generic Name by way of Example.*
I. Primæval Birds **Saururæ**	Teeth in the beak. Long lizard-like tail (feathered). Breast-bone with keel	1. Protornithes.	* Protornis.
		2. Archæopteryges.	* Archæopteryx.
II. Toothed Birds **Odontornithes**	Teeth in the beak. Short bushy tail (bushed). Breast-bone without keel	3. Hesperornithes.	* Hesperornis.
		4. Ichthyornithes.	* Ichthyornis.
III. Ostrich-like Birds **Ratitæ**	No teeth in the beak. Short bushy tail (bushed). Breast-bone without keel	5. Apterygidæ.	Apterix.
		6. Dinornithes.	* Dinornis.
		7. Casuaridæ.	Casuarius.
		8. Rheidæ.	Rhea.
		9. Struthionidæ.	Struthio.
IV. Keel-breasted Birds **Carinatæ**	No teeth in the beak. Short fan-tail (fanned). Breast-bone with keel	10. Dromæognathæ.	Tinamus.
		11. Spheniscidæ.	Aptenodytes.
		12. Pygopodes.	Colymbus.
		13. Longipennes.	Larus.
		14. Steganoporæ.	Pelecanus.
		15. Lamellirostres.	Cygnus.
		16. Ciconariæ.	Ardea.
		17. Grallæ.	Scolopax.
		18. Rasores.	Gallus.
		19. Gyrantes.	Columba.
		20. Passerinæ.	Fringilla.
		21. Macrochires.	Cypselus.
		22. Picariæ.	Picus.
		23. Coccyges.	Rhamphastus.
		24. Psittacidæ.	Psittacus.
		25. Raptatores.	Aquila.

birds), *Charadriornithes* (most of the wading-birds), *Alectorornithes* (most of the gallinaceous tribe), and *Coracornithes* (all the mass of climbing, perching, and singing birds). Among the Ratitæ Fürbringer distinguishes three different orders—the Cassowaries (*Hippalectryornithes*), the American ostriches (*Rheornithes*), and the African ostrich (*Struthiornithes*).

The critical and circumspect manner in which Fürbringer has phylogenetically treated the immense accumulation of material on the morphology of Birds, and the way he has made use of it in establishing his new system, is worthy of the highest praise. This distinguished anatomist has also for the first time set up stereometrical pedigrees (pp. 1119 and 1569 and Plates XXVII.–XXX. in his work). He there graphically gives a full demonstration of the bodily pedigree, by supplementing several vertical views (from different sides) by horizontal planimetric projections. The imperfect form in which, in my "General Morphology" (1866), I published the first sketches of my systematic pedigrees, and which I have endeavoured to improve in every new edition of my "History of Creation," necessarily remained unsatisfactory, for they were planned only upon vertical lines. The stereometrical form of the pedigree which Fürbringer now attempts for the first time, indicates a great advance in our phylogenetic knowledge and mode of statement. Any naturalist who wishes to obtain a clear insight into the complicated history and pedigree of any of the larger or smaller groups of forms, will have to follow Fürbringer's example. By "graphically representing the complicated tangle of the phylogenetic lines of development from different points of view," and by supplementing the vertical

views by horizontal projections (or transverse sections of the pedigree), a far clearer idea of the true relationships will be obtained than could otherwise be possible. The stereometric pedigree is certainly much more difficult to set up than the planimetric pedigree hitherto employed, but it is intellectually of much great value, and forms the goal for the progressive phylogeny of the future.

CHAPTER XXVI.

PEDIGREE AND HISTORY OF THE MAMMALIA.

The System of Mammals according to Linnæus and Blainville.—Three Sub-classes of Mammals (Ornithodelphia, Didelphia, Monodelphia).—Ornithodelphia, or Monotrema.—Egg-laying Mammals.—Beaked Animals (Ornithostoma) and Primæval Mammals (Promammalia).—Didelphia, or Marsupials.—Herbivorous and Carnivorous Marsupials.—Monodelphia, or Placentalia (Placental Animals).—Meaning of the Placenta.—Recent Palæontological Discoveries in Europe and North America.—Tertiary Placental Fauna.—Complete Pedigrees.—Six Legions and Twenty Orders of the Placentalia.—Their Typical Jaw.—Edentata, or Animals Poor in Teeth.—Cetacea and Sirenia (Whales).—Hoofed Animals.—Primary Hoofed Animals.—Single-hoofed and Double-hoofed Animals.—Animals with Proboscis.—Flat-hoofed Animals.—Rodents.—The Four Orders of Rapacious Animals (Creodonta, Insectivora, Carnivora, and Seals).—The Legion of the Primates : Semi-apes, Flying Animals, Apes, and Men.

THERE are only a few points in the classification of organisms upon which naturalists have always agreed. One of these few undisputed points is the privileged position of the class of Mammals at the head of the animal kingdom. The reason of this privilege consists partly in the special interest, also in the various uses and the many pleasures, which Mammals, more than all other animals, offer to man, and partly in the circumstance that man himself is a member of this class. For however differently in other respects man's position in nature and in the system of animals may have been regarded, yet no naturalist has

ever doubted that man, at least from a purely morphological point of view, belongs to the class of Mammals. From this there directly follows the exceedingly important inference that man is also by consanguinity a member of this class of animals, and has historically developed out of long since extinct forms of Mammals. This circumstance alone justifies us here in turning our especial attention to the history and the pedigree of Mammals. Let us, therefore, for this purpose first examine the groups of this class of animals.

Older naturalists, taking the formation of the jaw and feet into consideration, divided the class of Mammals into a series of from eight to sixteen orders. The lowest stage of the series was occupied by the whales, whose fish-like form of body seemed to differ most from man, who stands at the highest stage. Thus Linnæus distinguished the following eight orders: (1) Cetæ (whales); (2) Belluæ (hippopotami and horses; (3) Pecora (ruminating animals); (4) Glires (gnawing animals and rhinoceroses); (5) Bestiæ (insectivora, marsupials, and various others); (6) Feræ (beasts of prey); (7) Bruta (edentates and elephants); (8) Primates (bats, semi-apes, apes, and men). Cuvier's classification, which became the standard of most subsequent zoologists, did not rise much above that of Linnæus. Cuvier distinguished the following eight orders: (1) Cetacea (whales); (2) Ruminantia (ruminating animals); (3) Pachyderma (hoofed animals, with the exclusion of ruminating animals); (4) Edentata (animals poor in teeth); (5) Rodentia (gnawing animals); (6) Carnassia (marsupials, beasts of prey, insectivora, and bats); (7) Quadrumana (semi-apes and apes); (8) Bimana (man).

The most important advance in the classification of

Mammals was made as early as 1816 by the eminent anatomist Blainville, who has already been mentioned, and who first clearly recognized the three natural main groups or sub-classes of Mammals, and distinguished them according to the formation of their generative organs as *Ornithodelphia, Didelphia*, and *Monodelphia*. As this division is now justly considered by all scientific zoologists to be the best, on account of its solid foundation on the history of development, let us here keep to it also. The differences which separate these three sub-classes of Vertebrates from one another are so varied and important, that they correspond, in fact, to three distinct stages of the historical development of the class. It seems, therefore, appropriate here to place them together on the following table :—

Three Sub-classes of the Mammalia.	*Forked Animals* or *Monotrema* (*Prototheria* or *Ornithodelphia*).	*Pouched Animals* or *Marsupialia* (*Metatheria* or *Didelphia*).	*Placental Animals* or *Placentalia* (*Eutheria* or *Monodelphia*).
1. Propagation	By laying eggs	Bring forth living young	Bring forth living young
2. Eggs	Large, rich in yelk, with shell	Small, without shell	Small, without shell
3. Teats or Milk-warts	Absent	Present	Present
4. Placenta	Absent	Absent	Present
5. Cloacal formation	Permanent	Embryonal	Embryonal
6. Marsupial bones	Present	Present	Absent
7. Clavicles coalesced with the breast-bone	Coalesced	Not coalesced	Not coalesced
8. Coracoid bones	Fully developed	Quite degenerated	Quite degenerated
9. The Corpus callosum of the brain	Not developed	Not developed	Strongly developed
10. Temperature of the blood	Low (25° C.)	High (32–36° C.)	High (35–40° C.)

The size of the three sub-classes of Mammals is extremely different. Of the first and lowest, that of the Monotrema, we know only of two still living species, the Beaked animals of Australia. The second sub-class, which occupies a middle position in the historical and morphological development, is formed exclusively of the Marsupials; numerous forms of this class still live in Australia, and some in America. All the other Mammals, the main portion of the class so rich in forms, belong to the third sub-class, the Placentalia. And it is these latter which, since the beginning of the Tertiary period, have assumed the sovereignty over the whole tribe of Vertebrates, and which have produced such a quantity of interesting and important animal forms that the whole Cænozoic period might well be termed that of the Mammalia.

The first sub-class consists of the *Cloacal Animals*, or *Breastless Animals* (Monotrema, Ornithodelphia, or Prototheria). This class is now represented only by two species of living mammals, both of which are confined to Australia and the neighbouring islands of New Guinea and Van Diemen's Land, namely, the well-known Water Duck-bill (Ornithorhynchus paradoxus) with the beak of a bird, and the less-known Beaked Mole (Echidna hystrix and two kindred species), resembling a hedgehog. Both of these curious animals, which are classed in the order of *Beaked Animals* (Ornithostoma), are evidently the last surviving remnants of an animal group formerly rich in forms, which alone represented the Mammalia in the earlier secondary epoch, and out of which the second sub-class, the Didelphia, developed later, probably in the Trias or Jurassic period. Unfortunately, we as yet do not know with certainty of

any fossil remains of this most ancient primary group of Mammals, which we will call Primary Mammals (*Promammalia*). Yet they possibly comprise the oldest of all the fossil Mammalia known, namely, the *Microlestes antiquus*, of which animals, however, we as yet only know some few small molar teeth. These have been found in the uppermost strata of the Trias, in the Keuper, first in Germany (at Degerloch, near Stuttgart, in 1847), later also in England (at Frome), in 1858. Similar teeth have lately been found also in the North American Trias, and have been described as Dromatherium sylvestre. These remarkable teeth, from the characteristic form of which we can conclude that they belonged to an insectivorous mammal, are the only remains of Mammals as yet found in the older secondary strata, namely, in the Trias. It is possible, however, that besides these many of the other mammalian teeth found in the Jura and Chalk systems, which are still generally ascribed to Marsupials, in reality belong to true Promammalia. This cannot be decided with certainty owing to the absence of the characteristic soft parts. In any case, numerous Monotrema, with well-developed teeth and cloaca, must have preceded the advent of Marsupial animals.

Blainville called the Monotrema "Ornithodelphia" because their organs of propagation showed agreements with those of Birds and Reptiles. This important similarity is obviously the result of an inheritance from a common primordial group, the Protamnia or Proreptilia. On account of it, and more especially because of the structure of the female organs, Lamarck as early as 1809 had come to the conclusion that the Beaked animals did not bring forth young alive, like other mammals, but that they laid eggs

like the Sauropsida. This conjecture was not confirmed till seventy-five years later by direct observation. It was only in 1884 that Haacke and Caldwell, almost simultaneously and independently of one another, discovered that the Monotrema laid large, soft-shelled eggs rich in yolk, like the Reptiles. Ornithorhynchus hides its egg in a hole in the earth, Echidna hides its in a brooding pouch on its belly. The young Monotrema that creep out of the egg do not suck milk from their mother like other mammals; but they lick up the nutritive perspiration of their mother. According to Gegenbaur's interesting discovery, the nutritive fluid in this case is furnished by the enlarged perspiratory glands of the mammary pouch; whereas the milk of Marsupials and Placental animals is developed by the fatty glands. These two sub-classes alone possess actual teats for sucking, and are hence also called "Animals with teats, or Mastozoa;" in the Monotrema they are still altogether wanting, hence their name of "Teatless animals, or Amasta."

The designation, "Cloacal animals" (*Monotrema*), has been given to the Ornithodelphia on account of the cloaca which distinguishes them from all other Mammals; but which, on the other hand, makes them agree with Birds, Reptiles, and Amphibia, in fact, with the lower Vertebrata. The formation of the cloaca consists in the last portion of the intestinal canal receiving the opening of the urogenital apparatus, that is, the united urinary and genital organs, whereas in all other Mammals (Didelphia as well as Monodelphia) these organs have an opening distinct from that of the rectum. However, in these latter also the cloaca formation exists during the first period of their embryonal life, and the separation of the two openings takes place

only at a later date (in man about the twelfth week of development). The Cloacal animals have also been called "*Forked animals,*" because the collar-bones, by means of the breast-bone, have become united into one piece, similar to the well-known fork-bone, or merry-thought, in birds. In all other Mammals the two collar-bones remain separated in front and do not fuse with the breast-bone. Moreover, the coracoid bones are much more strongly developed in the Monotrema than in the other Mammalia, and are connected with the breast-bone as a couple of strong independent bones. In the Marsupials and Placental animals, on the other hand, they have become quite degenerated; sometimes they have disappeared, sometimes have grown to the shoulder-blade, and are visible only as short processes.

In many other characteristics also—especially in the formation of their auricular labyrinth and their brain—Beaked animals are more closely allied to the other Vertebrata than to Mammals, so that some naturalists have been inclined to separate them from the latter as a special class. Thus, for instance, the temperature of the blood (25° C.) is considerably lower than in the case of the other mammals (35°–40°). On the other hand, in the structure of their heart and of the aorta, but especially by the characteristic hairiness of the skin, the structure of the vertebral column and of the skull, etc., it is distinctly evident that they must be classed among the Mammals possessing significant resemblances to the primary group of the ancient Proreptilia.

The curious formation of the beak in the two still living Beaked animals, which is connected with the suppression of the teeth, must evidently not be looked upon as an essential feature of the whole sub-class of Cloacal animals,

but as an accidental character of adaptation distinguishing the last remnant of the class as much from the extinct main group, as the formation of a similar toothless snout distinguishes many toothless animals (for instance, the ant-eater) from the other Placental animals. It is probable that the primary forms of our present Beaked animals lost their teeth in much the same way as our present Birds, which were originally derived from Toothed Birds. The unknown, extinct Primary Mammals, or Promammalia—which lived during the Trias period, and of which the two still living orders of Beaked animals represent but a single degenerated branch developed on one side—probably possessed a very highly developed jaw like the Theriosauria from which they are descended, and like the marsupial animals which first developed from them.

Marsupial, or Pouched Animals (*Didelphia*, or *Marsupialia*, called *Metatheria* by Huxley), the second of the three sub-classes of Mammals, form in every respect—both as regards their anatomy and embryology, as well as their genealogy and history—the transition between the other sub-classes, the Cloacal and Placental animals. Numerous representatives of this group still exist, especially the well-known kangaroos, pouched rats, and pouched dogs; but on the whole this sub-class, like the preceding one, is evidently approaching its complete extinction, and the living members of the class are the last surviving remnants of a large group rich in forms, which represented the Mammalia during the more recent Secondary and the earlier Tertiary periods. The Marsupial animals probably developed towards the middle of the Mesolithic epoch (during the Trias or Jura) out of a branch of the Cloacal animals, and in the beginning or

towards the end of the Chalk period again, the group of Placental animals arose out of the Marsupials, and the latter then succumbed to the former in the struggle for life. All the fossil remains of Mammals known to us from the Secondary epoch, seem to belong either exclusively to Marsupials, or partly perhaps to Cloacal animals. At that time Marsupials were distributed over the whole earth; even in Europe (France and England), well-preserved fossil remains of them have been found. On the other hand, the last offshoots of the sub-class now living are confined to a very narrow tract of distribution, namely, to Australia, the Australasian, and a small part of the Asiatic, Archipelago, There are a few species still living in America (of the family of pouched rats), but at the present day not a single marsupial animal lives on the continent of Asia, Africa, or Europe.

The name of Pouched animals is given to the class on account of the purse-shaped pouch (marsupium) existing in most instances on the abdominal side of the female animals, in which the mother carries about her young for a considerable time after their birth. This pouch is supported by two characteristic marsupial bones, also existing in Cloacal animals, but not in Placental animals. The young Marsupial animal is born in a much more imperfect form than the young Placental animal, and only attains the same degree of development which the latter possesses directly at its birth, after it has developed in the pouch for some time. In the case of the giant kangaroo, which attains the height of a man, the newly born young one, which has been carried in the maternal womb not much longer than five weeks, is not more than an inch in length, and only attains its

essential development subsequently, in the pouch of the mother, where it remains about nine months attached to the nipple of the mammary gland.

The different divisions generally distinguished as families in the sub-class of Marsupial animals, deserve in reality to rank as independent orders, for they differ from one another in manifold differentiations of the jaw and limbs, in much the same manner, although not so sharply, as the various orders of Placental animals. In a way they represent the latter. It is evident that adaptation to similar conditions of life has effected entirely coincident or analogous transformations of the original fundamental form in the two sub-classes of Marsupials and Placental animals; a proof of the power of the principle of convergence. Accordingly, about eight orders of Marsupial animals may be distinguished, the one half of the main group or legion being herbivorous, the other half carnivorous. The oldest fossil remains of the two legions (if the previously mentioned Microlestes and the Dromatherium of the Trias are not included) occur in the Jurassic strata, namely, in the slates of Stonesfield, near Oxford. These slates belong to the Bath, or the Lower Oolite formation—strata which lie directly above the Lias, the oldest Jura formation. It is true that the remains of Marsupials found in the slates of Stonesfield, as well as those which were found later in the Purbeck strata, consist only of lower jaws. But fortunately the lower jaw is just one of the most characteristic parts of the skeleton of Marsupials. For it is distinguished by a hook-shaped process of the angle of the lower jaw turning downwards and backwards, which neither occurs in Placental nor in the (still living) Cloacal

animals, and, from the existence of this process on the lower jaws from Stonesfield, we may infer that they belonged to Marsupials.

The first and older legion of the Marsupials, which are derived from a branch of the Promammalia, is formed by the Carnivorous Marsupials (*Zoophaga*). It includes four different main groups or orders. The earliest of these is that of the Primæval Marsupials, or the insectivorous Marsupials (Prodidelphia); these probably include the primary forms of the whole legion, and perhaps of the whole subclass. At all events, all the lower jaws discovered in the slates of Stonesfield (with the exception of Plagiaulax and Stereognathus) belong to insectivorous Marsupials, of which the still living *Myrmecobius* is the nearest relative. However, in a portion of these oolitic, primæval Marsupials, the number of teeth was much greater than in the case of most other Mammals. For every lower jaw piece of *Thylacotherium* contained sixteen teeth (three incisors, one canine tooth, six pseudo, and six genuine molars). If the unknown upper jaw contained as many teeth, *Thylacotherium* possessed no less than sixty-four teeth, just double the number possessed by man. The Primæval Marsupials correspond upon the whole to the Insectivora among the Placental animals, which order includes hedgehogs, moles, and shrew-mice. A second order, which has probably developed out of a branch of the former, is represented by the Snouted or Toothless Marsupials (*Edentula*), which—owing to their long proboscis, the degenerated jaw, and a similar mode of life—correspond to the Edentata among the Placentalia, more especially to the Ant-eaters (*Tarsipes*). On the other hand, the Rapacious Marsupials (*Creophaga*), in their mode of life and formation

of jaw, resemble the Carnivora among the Placental animals. These include the pouched marten (*Dasyurus*) and the pouched wolf (*Thylacinus*) of Australia. Although the latter attains the size of a wolf, it is a dwarf compared with the extinct marsupial lions of Australia (*Thylacoleo*), which were at least as large as lions, and possessed huge canine teeth of more than two inches in length. The fourth carnivorous order is formed by the Marsupials with hands, or the ape-footed Marsupials (*Pedimana*) which live in the warmer regions of America. They are frequently to be seen in zoological gardens, being the various species of the genus Didelphys, known under the names of pouched rats, bush-rats, or opossum. On their hind feet the thumb is opposable to the four toes, as in a hand, and by this they are directly allied to the Semi-apes, or Prosimia, among Placental animals. It is possible that these latter are really next akin to the Marsupials with hands, and that they have developed out of long since extinct ancestors of the latter.

Of the second legion, the Herbivorous Marsupials (*Phytophaga*), we as yet know of only a few fossils from the Jura, among these the *Stereognathus oolithicus* from the slates of Stonesfield (Lower Oolite), and the *Plagiaulax Becklesii* from the middle Purbeck strata (Upper Oolite). On the other hand, in Australia are to be found fossil remains of colossal, extinct herbivorous Marsupials of the Diluvial period (*Diprotodon* and *Nototherium*), which were far larger than the largest existing Marsupials. The *Diprotodon australis*, whose skull alone is three feet long, exceeded even the River-horse, or Hippopotamus, in size, and upon the whole resembled it in the unwieldy and clumsy form of

its body. This extinct group, which probably represented the gigantic placental hoofed animals of the present day—the hippopotami and rhinoceroses—may be called Hoofed Marsupials (*Barypoda*). Closely allied to them is the order of kangaroos, or Leaping Marsupials (*Macropoda*). In their shortened fore legs, their very lengthened hind legs, and very strong tail, which serves as a jumping-pole, they correspond with the leaping mice in the class of Rodents. Their jaw, however, resembles that of horses, and their complex stomach that of Ruminants. A third order of Herbivorous Marsupials corresponds in its jaws to Rodents, and in its subterranean mode of life, especially, to rabbits. Hence they may be termed Rodent Marsupials or root-eating pouched animals (*Rhizophaga*). They are now represented only by the Australian wombat (*Phascolomys*). A fourth and last order of Herbivorous Marsupials is formed by the climbing or Fruit-eating Marsupials (*Carpophaga*), whose mode of life and structure resembles partly that of squirrels, partly that of apes (*Phalangista, Phascolarctus*).

The third and last sub-class of mammals comprises the Placental Animals, or Placentals (*Monodelphia*, or *Placentalia*). It is by far the most important, comprehensive, and most perfect of the three sub-classes; for the class includes all the known mammalia, with the exception of Marsupials and Beaked animals. Man also belongs to this sub-class, and has developed out of its lower members.

All Placental animals, as their name indicates, are distinguished from all other mammals, more especially by the formation of a so-called *placenta*. This is a very peculiar and remarkable organ, which plays an exceedingly im-

portant part in nourishing the young one developing in the maternal body. It develops out of the embryonic allantois, which in the other Amniota protrudes from the intestine of the embryo in the form of a bladder with a rich supply of blood-vessels. The placenta (also called after-birth) is a soft, spongy, red body, which differs very much in form and size, but which consists for the most part of an intricate network of veins and blood-vessels. Its importance lies in the exchange of substance between the nutritive blood of the maternal womb, or uterus, and the body of the germ, or embryo (see vol. i. p. 342). This very important organ is developed neither in Marsupials nor in Beaked animals. But Placental animals are also distinguished from these two sub-classes by many other peculiarities, thus more especially by the absence of marsupial bones, by the higher development of the internal sexual organs, and by the more perfect development of the brain, especially of the so-called callous body or beam (*corpus callosum*), which, as the intermediate commissure, or transverse bridge, connects the two hemispheres of the cerebrum with each other. Placental animals also do not possess the peculiar hooked process of the lower jaw which characterizes Marsupials. The classification of the most important characteristics of the three sub-classes, given above on p. 327, will best show how Marsupials, in these anatomical respects, stand midway between Cloacal and Placental animals.

Placental animals are more variously differentiated and perfected, and this, moreover, in a far higher degree, than Marsupials, and they have, on this account, long since been arranged into a number of orders, differing principally in the formation of the jaws and feet. As a rule, our Manuals

on Zoology at present enumerate from ten to twelve orders of Placental animals, whilst all the Marsupials are united into one order, and all the Beaked animals likewise. However, owing to the grand palæontological discoveries of the last two decades, our views as regards the number, extent, and relationships between the orders, in fact our whole system of the Placentalia, has been completely altered. Rütimeyer's investigations on the fauna of the lake-dwellings, and especially on the phylogeny of the Hoofed animals, Gaudry's discovery of an astonishing wealth of Miocene Placentalia in Greece (at Pikermi and Marathon), and Filhol's even more valuable discoveries from the Eocene formations in South-western France (near Quercy), as well as numerous smaller contributions to science by other able palæontologists in England, Germany, France, and Italy, give us unquestionable proofs that Europe, during the Tertiary period, was densely inhabited by a mass of different species of Mammals surpassing that of the richest tropical regions of our day. But the systematic classification of the Mammalia has been even more radically affected by the astonishing discoveries which Cope and Marsh, the two distinguished North American palæontologists, have made during the last ten years, and which furnish valuable data for the phylogeny of the Mammalia. Their wonderful investigations produced a new world of Tertiary hoofed animals, beasts of prey, and other Placentalia—some representatives of entirely new orders, compared with which our living fauna appears but a poor remnant. On account of the number and variety of the extinct species, the size and strange shapes of many of the forms, the divergence of the smaller and larger groups, but, above all, the importance

of their phylogenetic connections, this Tertiary fauna of Placental animals deserves as important a position in "the epoch of Mammals" as the Mesozoic Saurians in the "epoch of Reptiles."

What must be specially noted here is that this collection of fossil Tertiary Placentalia is one of rare completeness. Thanks to the great mass of skeletons that have often been embedded together, and the good state of preservation of all the bony parts, we are now as intimately acquainted with the bony framework of many of these long since extinct hoofed and rapacious animals as we are with that of those now living. But, above all, it has in many cases now become possible so perfectly to restore the whole series of ancestral forms—the direct phylogenetic connection between the different genera that have arisen one out of the other—that we now have *a complete palæontological pedigree* visibly before our eyes; for instance, in the case of the *Horse*, justly called the "show horse" of palæontological phylogeny. In fact, what the opponents of the theory of descent doubted to be in any way possible, what cautious inquirers demanded as proofs—an uninterrupted series of fossilized, intermediate species as ancestors of the living animals—which, however, were unfortunately not obtainable owing to the well-known incompleteness of our palæontological records of creation—this has now become a most welcome actuality in the case of many groups of the Placentalia.

Of course the most complete palæontological discoveries are never sufficient for giving a perfectly satisfactory idea of the organization of extinct animals; for, in most cases, naturally, it is only the skeleton that can be preserved in a

fossil state; and only imperfect inferences can be drawn from the form of the bony skeleton as regards the nature of the other parts, *e.g.* of the brain, the muscles, etc. We learn absolutely nothing of the formation of the most important soft parts of the body; for instance, of the heart, the intestines, placenta, etc.). But, fortunately, in the case of Mammals, the nature of the hard skeleton is of such special value to our knowledge of the natural relationships, that we can safely include the fossil Placentalia of the Tertiary period into our new system of the Mammalia. The differences in the formation of the more important parts of the skeleton appear to me so important in this large sub-class of Mammals, that I cannot distinguish fewer than twenty orders of the Placentalia. They can again be sub-divided into six larger main orders or legions (p. 344). Of these the *Edentata* and the Whale-like animals (*Cetomorpha*) occupy the lowest stage; the herbivorous hoofed animals (*Ungulata*) and Rodents (*Rodentia*) take a middle rank; and the carnivorous beasts of prey (*Carnassia*) stand at the top, with the *Primates* above them.

The important question of the phylogenetic connection between these legions, or the great main divisions of the Placentalia, is difficult to answer. For while we can form tolerably satisfactory ideas as regards the descent of the groups of forms within each order, and generally also as regards the primary relationship of the orders in each legion, yet, on the other hand, the primæval roots of the latter remain quite obscure. Some zoologists consider the Placental group to be of *monophyletic* origin, *i.e.* they assume that the placenta developed only *once* out of the allantois in *one* group of the Marsupials, and that, accord-

ingly, the very ancient and first placental animal which arose in this manner (the Proplacental) became the common ancestor of all the rest. Other zoologists, however, are more disposed to consider the origin of the Placentalia to have been *polyphyletic;* hence that the important process of the allantois being changed into the placenta occurred several times, and that, accordingly, *several* primary groups of Placental animals arose out of several different ancestral lines of Marsupials. Reasons can be adduced in favour of each of these opposite hypotheses; but it seems as if the latter were at present the more probable.

Unfortunately, palæontology has not as yet given us any safe information on the subject. From the Chalk period, during which the origin of the Placentalia probably took place, we have as yet only very few and unimportant fossil remains of mammals.

The jaw of the *Proplacentalia,* the earliest primary forms of all the Placental animals, probably contained very numerous and equal teeth, of a simple conical form, which were never changed; their dentition would resemble that of our present Armadilloes and the Dolphins, as well as of the earlier Reptiles, and what we must presume to have been the dentition of the Promammalia and the primary forms of the Marsupials. This primitive form of dentition subsequently developed into a definite, very characteristic construction, which is first met with towards the beginning of the Tertiary period. This "typical Placental dentition," from which we derive all the different forms of dentition in the Placentalia (with the exception of the Edentata and Cetacea), consists of 44 teeth; namely, in all of the four halves of the jaw are 3 incisors, 1 canine, 4

premolars, and 3 molars—the dental formula being $\frac{3.1.4.3}{3.1.4.3}$. As this typical form of dentition is met with as early as the beginning of the Eocene period, both in the earliest Carnivora as well as the earliest Herbivora, we may assume that it had been transmitted by inheritance from a very ancient, primary form of Placental animal (perhaps even belonging to the Chalk period) to the different orders of this sub-class. The differences of the four kinds of teeth (at first scarcely appreciable) became more and more marked as the jaw differentiated, and at the same time the teeth gradually became reduced in number.

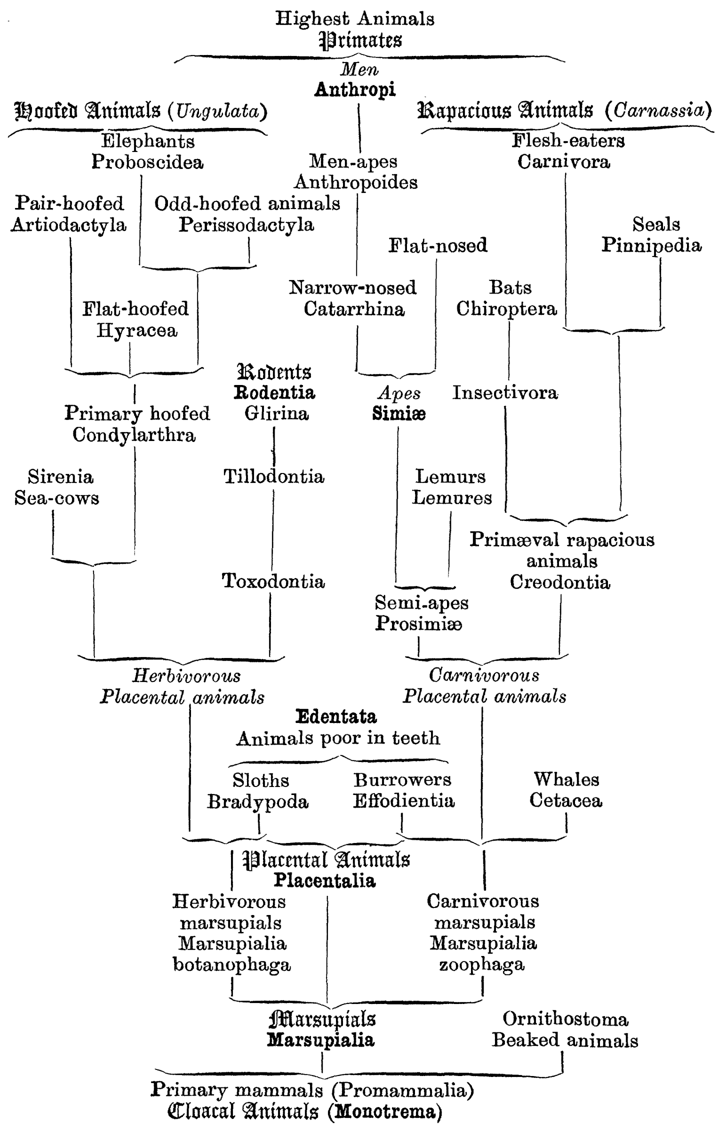
The legion of the *Edentata*, or animals poor in teeth, may be regarded as a remnant of an ancient group of Placentalia. The dentition here retains the Reptilian character described above; sometimes there are only a few teeth, sometimes a great number (about a hundred), all pointed and alike without any proper fang; in many (the ant-eaters) they have all been lost (as in the Echidna). The Edentata, moreover, also show resemblances to the Reptiles by the lower stage of development of their brain, and by their peculiar dermal covering (scales of the Manis, and bony plates of the Armadilloes). The legion includes two very different orders, which are perhaps not closely allied—the Burrowers and the Sloths. The order of the Burrowers (*Effodientia*) comprises the two sub-orders of the Insect-eaters (*Vermilinguia*), to which the Scaly Ant-eaters belong, and the Armadilloes (*Cingulata*), which were formerly represented by the gigantic Glyptodons. The order of Sloths (*Bradypoda*) comprises two sub-orders of small still-existing Dwarf-sloths (*Tardigrada*) and the extinct unwieldy Giant-sloths (*Gravigrada*). The enormous

SYSTEMATIC SURVEY

Of the 9 *Legions and* 30 *Orders of the Mammalia.*

(The extinct groups are marked *).

Legions.	*Orders.*	*Orders.*	*Example.*
I. Cloacal Animals. **Monotrema.**	1. Promammalia.	* Primæval mammals.	Prototherium.
	2. Ornithostoma.	Beaked animals.	Ornithorhynchus.
II. Carnivorous Marsupials. **Zoophaga.**	3. Prodidelphia.	Primæval marsupials.	Plascolotherium.
	4. Edentula.	Long-snouted marsupials.	Tarsipes.
	5. Creophaga.	Pouched martens.	Thylacinus.
	6. Pedimana.	Pouched rats.	Didelphys.
III. Herbivorous Marsupials. **Phytophaga.**	7. Carpophaga.	Pouched mice.	Phalangista.
	8. Rhizophaga.	Pouched rodents.	Phascolomys.
	9. Barypoda.	Hoofed marsupials.	Diprodon.
	10. Macropoda.	Kangaroos.	Halmaturus.
IV. Animals poor in teeth. **Edentata.**	11. Effodientia.	Burrowers.	Dasypus.
	12. Bradypoda.	Sloths.	Bradypus.
V. Whale-like Animals. **Cetomorpha.**	13. Cetacea.	Whales.	Delphinus.
	14. Sirenia.	Sea-cows.	Halicore.
VI. Hoofed Animals. **Ungulata.**	15. Condylartha.	* Primæval hoofed animals.	Phenacodus.
	16. Perissodactyla.	Odd-hoofed animals.	Equus.
	17. Artiodactyla.	Pair-hoofed.	Sus.
	18. Proboscidæ.	Trunked hoofed animals.	Elephas.
	19. Hyracea.	Flat-hoofed.	Hyrax.
VII. Rodents. **Rodentia.**	20. Tillodontia.	* Hoofed rodents.	Tillotherium.
	21. Toxodontia.	* Arrow-toothed.	Toxodon.
	22. Glirina.	Squirrels.	Sciurus.
VIII. Rapacious Animals. **Carnassia.**	23. Creodontia.	* Primæval rapacious animals.	Lepictis.
	24. Insectivora.	Insect-eaters.	Erinaceus.
	25. Carnivora.	Rapacious land-animals.	Canis.
	26. Pinnipedia.	Rapacious sea-animals.	Phoca.
IX. Highest Animals. **Primates.**	27. Prosimiæ.	Semi-apes.	Lemur.
	28. Chiroptera.	Bats.	Vespertilis.
	29. Simiæ.	Apes.	Gorilla.
	30. Anthropi.	Men.	Homo.


Highest Animals
Primates
Men
Anthropi
Hoofed Animals (*Ungulata*)
Rapacious Animals (*Carnassia*)
Elephants
Proboscidea
Men-apes
Anthropoides
Flesh-eaters
Carnivora
Pair-hoofed
Artiodactyla
Odd-hoofed animals
Perissodactyla
Seals
Pinnipedia
Flat-nosed
Narrow-nosed
Catarrhina
Bats
Chiroptera
Flat-hoofed
Hyracea
Rodents
Rodentia
Glirina
Apes
Simiæ
Insectivora
Primary hoofed
Condylarthra
Sirenia
Sea-cows
Tillodontia
Lemurs
Lemures
Primæval rapacious
animals
Creodontia
Toxodontia
Semi-apes
Prosimiæ
Herbivorous
Placental animals
Carnivorous
Placental animals
Edentata
Animals poor in teeth
Sloths
Bradypoda
Burrowers
Effodientia
Whales
Cetacea
Placental Animals
Placentalia
Herbivorous
marsupials
Marsupialia
botanophaga
Carnivorous
marsupials
Marsupialia
zoophaga
Marsupials
Marsupialia
Ornithostoma
Beaked animals
Primary mammals (Promammalia)
Cloacal Animals (Monotrema)

fossil remains of these colossal Herbivora point to the fact that the whole legion is dying out. The close resemblances between the still living Edentata of South America and the extinct colossal forms in the same part of the globe made such an impression upon Darwin, when he first visited South America, that they even then suggested to him the fundamental thought of the theory of descent. Yet it is precisely the genealogy of this legion which is most difficult.

The *Whale-like animals* (*Cetomorpha*), also often called Fish-mammals, or "Whale-fish," are another very ancient and isolated legion of the Placental animals. Owing to their fish-like shape, these inhabitants of the water were formerly classed among the Fishes. However, this resemblance to fish is only a matter of convergence, and is the result of adaptation to a similar mode of life. There can be no doubt that all Cetomorpha are descended from four-footed Placental animals that lived on land (perhaps in the Chalk period). Their origin, however, is distinctly twofold, inasmuch as the two orders of the legion, the Cetacea and Sirenia, although extremely alike outwardly, are essentially different in internal structure; their resemblance is likewise the result of convergence.

The principal portion of the Cetomorpha belong to the order of Carnivorous whales (*Cetacea*). Numerous genera and species still inhabit all our oceans, some even rivers (for instance, the "Dolphin of the Ganges"). The primary group of this order we consider to be the sub-order of Toothed whales or Dolphins (*Denticete*). They mostly possess, in their jaws, a great number of small teeth, all like, of a simple conical form (like those of the Arma-

dilloes). They are probably derived from a very ancient primary group of the Placentalia which lived in the Secondary period. As two diverging branches, there arose out of the Dolphin group two higher sub-orders: on the one hand, the Zeuglodonts (*Zeuglocete*); on the other, the gigantic Right Whales (*Mysticete*). The latter includes the largest of all living animals, the giant whales (*Megaptera*), attaining a length of over a hundred feet. In their mouth, in place of teeth, they have the so-called beards of whalebone, a huge sieve-like apparatus. But in embryos the jaw shows the rudiments of small teeth like the Dolphin's, which is a proof of their descent from the latter.

The Herbivorous Sea-Cows (*Sirenia*) are of an entirely different origin. Of this order there now exist only two species (*Halicore* in the Indian Ocean, and *Manatus* in the Atlantic); both possess but few teeth. Both of them—like the Cetacea—have spindle-shaped bodies like fish, with a thick almost naked skin, a broad horizontal tail-fin, and a pair of five-toed breast-fins (fore legs). The hind legs, however (the ventral fins), have been lost, and only a few bones in the interior now exist as their rudiments. But some of the old Eocene Sirenia (*Prorastomus* and others) still possessed five-toed hind legs. They likewise had the typical dentition of the Placentalia with forty-four teeth ($\frac{3.1.4.3}{3.1.4.3}$, see above, p. 343). As these Herbivorous Sirenia, as regards structure of skull and typical dentition, appear closely allied to the earliest Eocene Hoofed animals, there can probably be no doubt that they were actually descended from them. Thus the Cetomorpha form a diphyletic group; the carnivorous Cetacea and the herbivorous Sirenia are two different tribes, that have arisen out of entirely different

groups of four-footed land Placental animals by adaptation to a fish's mode of life.

One of the most important and most extensive groups of the Placentalia is formed by the great legion of the Hoofed animals (*Ungulata*). They are in many respects one of the most interesting classes of Mammals. They distinctly show that a true understanding of the natural relationship of animals can never be revealed to us merely by the study of living forms, but only by an equal consideration of their extinct and fossil blood-relations and ancestors. If, as is usually done, only the living Hoofed animals are taken into consideration, it seems quite natural to divide them into three entirely distinct orders, namely: (1) Horses, or Single-hoofed animals (*Solidungula*, or *Equina*); (2) Ruminating animals, or Double-hoofed (*Bisulca*, or *Ruminantia*); and (3) Thick-skinned, or Many-hoofed (*Multungula*, or *Pachyderma*). But as soon as the extinct Hoofed animals of the Tertiary period are taken into consideration—of which animals we possess very numerous and important remains—it is seen that this division, but more especially the limitation of the Multungula, is completely artificial, and that these three groups are merely top branches lopped from the pedigree of Hoofed animals, which are most closely connected by extinct intermediate forms. The one half of the Multungula—rhinoceroses, tapirs, and palæotheria—manifest the closest relationships to horses, and have, like them, odd-toed feet. The other half of the Multungula, on the other hand—pigs, hippopotami, and anoplotheria—are, on account of their double-toed feet, much more closely allied to the Ruminants than to the former. Hence we must, in the first place, among

Hoofed animals distinguish the two orders of Pair-hoofed and Odd-hoofed (*Artiodactyla* and *Perissodactyla*), as two natural groups which developed as diverging branches out of the old tertiary group of Primary Hoofed animals (*Condylarthra*).

Out of the same primary group, however, there likewise developed two other interesting orders, which show affinity to the Rodents, namely, the Flat-hoofed animals (*Hyracea*) and the animals with proboscis (*Proboscidea*); the latter include the Dinotheria and Elephants. Thanks to the grand advances of palæontology during the last decade, we can now very clearly survey the relationships between these five orders of Hoofed animals and their numerous families.

We consider the Primary Hoofed animals (*Condylarthra* or *Protungulata*) as the primary group of all Hoofed animals. The oldest Ungulata (discovered in the Eocene of North America), in the formation of their skeleton and limbs, their skull and their dentition, are more closely allied to the oldest Placentalia of other orders (especially to the Rapacious animals) than to the other Hoofed animals. They still possess the full typical dentition of the Placentalia (see p. 343) and the forty-four teeth no less differentiated than in all other Hoofed animals. And this applies also to the five-toed feet, the toes of which are pretty equally developed. Probably the other Ungulata have developed out of this primæval primary group as four diverging branches. The *Periptychida* lead over to the Artiodactyla, the *Phenacodontida* to the Perissodactyla.

The order of Odd-hoofed animals (*Perissodactyla*) includes those Ungulata in which the middle (or third) toe of the foot is more strongly developed than the others, so that

it forms the actual centre of the hoof. The Perissodactyla may, in the first place, be divided into two sub-orders, the tribe of Rhinoceroses and the Horse tribe. The Rhinoceros tribe may also be termed the division of the Primæval tapirs (*Brontotapiri*). This subdivision includes the primæval, common primary group of all the Perissodactyla, which are found in a fossil state in the oldest Eocene strata, namely, the *Coryphodontia*. The group of the Rhinoceros tribe (*Nasicornia*) is directly allied to them. In addition to the living rhinoceros, the group includes the remarkable extinct family of the Brontotherida and Elasmotherida. The second sub-order of the Perissodactyla is formed by the Horse tribe, the Hippotapiri. It also comprises two kindred groups (see p. 352).

The Eocene Palæotherida may be regarded as the common primary group of the tapir and horse tribes, which developed out of it as diverging branches. The pedigree of the Horses are of special interest to the history of descent, for, owing to numerous fossil testimonies, its pedigree can be drawn up step by step with unusual completeness, as may be seen from the accompanying table (p. 351). All the fossil intermediate stages between the earliest Eocene five-toed Coryphodon and our present one-toed horses have been found in America. This is the more interesting as, at the time of the discovery of America, the horse, as is well known, had become extinct in its original home.

The second main group of Hoof-animals, the order of Pair-hoofed (*Artiodactyla*), comprises those Ungulata in which the middle (third) and fourth toe of the foot are almost equally developed, so that the space between the two forms the central line of the entire foot. The order is

PEDIGREE OF HORSES.

[N.B.—This table shows how the one-toed hoof of our present Horses arose by degeneration from the three-toed foot of the Miocene Middle Horse, and how the latter arose out of the five-toed foot of the earliest Eocene Perissodactyla. All the intermediate stages have been found fossil in North America.]

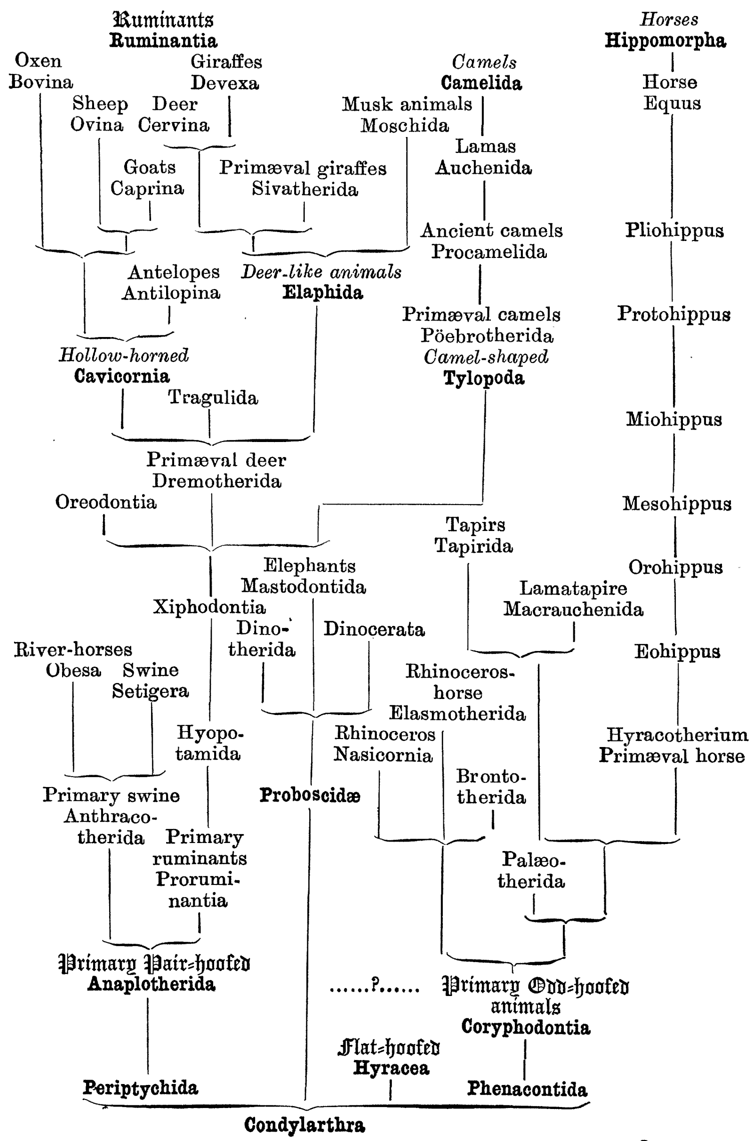
Species of Horse.	*Tertiary Strata.*	*Fore Leg.*	*Hind Leg.*
Living horse *Equus*	**Present** *and* **Quaternary**	1 toe	1 toe
Upper Pliocene horse *Pliohippus*	**Upper Pliocene**	1 principal toe and 2 secondary toes	1 toe and 2 rudiments
Lower Pliocene horse *Protohippus* (*Hipparion*)	**Lower Pliocene**	1 principal toe and 2 secondary toes	1 principal toe and 2 secondary toes
Upper Miocene horse *Miohippus* (*Anchitherium*)	**Upper Miocene**	3 toes, the middle one larger	3 toes, the middle one larger
Lower Miocene horse *Mesohippus*	**Lower Miocene**	3 toes and 1 rudiment	3 toes
Upper Miocene horse *Orohippus*	**Upper Eocene**	4 toes	3 toes
Primæval horse (primary form of horse) *Eohippus*	**Middle Eocene**	4 toes and 1 rudiment	3 toes
Primary form of the horse tribe *Hyracotherium*	**Lower Eocene**	5 toes, the middle one larger	3 toes and 1 rudiment
Primary form of all Odd-hoofed animals *Coryphodon*	**Lowest Eocene**	5 toes, the middle one somewhat larger	5 toes, the middle one somewhat larger
Ancestors of the Perissodactyla *Phenacodus*	**Lowest Eocene** (and Chalk ?)	5 toes almost equal	5 toes almost equal

SYSTEMATIC SURVEY

Of the Orders and Families of the Hoofed Animals (Ungulata).

(N.B.—The extinct families are marked with an asterisk.)

	Orders of the Hoofed Animals.	*Sections of the Hoofed Animals.*	*Families of the Hoofed Animals.*	*Systematic Name.*
	I. Primæval Hoofed Animals. **Condylarthra.**	1. Phenacodontida	Ancestors of the odd-hoofed animals.	*Phenacodon. *Anacodon.
		2. Periptychida	Ancestors of the pair-hoofed animals.	*Periptychus. *Zetodon.
II. Odd-hoofed Animals. **Perissodactyla.**	II. A. Primæval Tapirs. **Brontotapiri.**	3. Primæval tapirs *Protapiri*	Primæval odd-hoofed. Lophiodonta.	*Coryphodontia. *Lophiodontia.
		4. Rhinoceroses *Nasicornia*	Brontotheria. Rhinoceroses.	*Brontotherida. Rhinocerata.
	II. B. Tapir Horses. **Hippotapiri.**	5. Tapirs *Tapiromorpha*	Palæotheria. Tapirs.	*Palæotherida. Tapirida.
		6. Horses *Hippomorpha*	Middle horses. Horses.	*Anchitherida. Equina.
III. Pair-hoofed Animals. **Artiodactyla.**	III. A. Swine-shaped **Chœromorpha** or Animals with tuberculate teeth. **Bunodonta.**	7. Swine-shaped *Setigera*	Primæval pair-hoofed animals. Primæval pigs. Swine.	*Anoplotherida. *Anthracotherida. Suillida.
		8. Plump animals *Obesa*	Swine-horses. River-horses.	*Chœropotamida. Hippopotamida.
	III. B. Ruminants. **Ruminantia** or Animals with crescentic teeth. **Selenodontia.**	9. Primæval ruminants *Proruminantia*	Oreodontia. Dremotheria. Musk deer.	*Hyopotamida. *Dremotherida. Tragulida.
		10. Camel-shaped animals *Tylopoda*	Primæval camels. Ancient camels. Lamas. Camels.	*Pöebrotherida. *Procamelida. Auchenida. Camelida.
		11. Deer-like animals *Elaphida*	Musk animals. Deer. Giraffes.	Moschida. Cervina. Devexa.
		12. Hollow-horned animals *Cavicornia*	Gazelles. Goats. Sheep. Oxen.	Antilopina. Caprina. Ovina. Bovina.
	IV. Trunked Animals. **Proboscidea.**	13. Dinocerata		Dinoceras.
		14. Dinotherida		Dinotherium.
		15. Elephantida	Elephants.	Elephas.
	V. Flat-hoofed Animals. **Hyracea.**	16. Lamnungia	Rock-conies.	Hyrax.


Ruminants
Ruminantia
Horses
Hippomorpha
Oxen
Bovina
Giraffes
Devexa
Camels
Camelida
Horse
Equus
Sheep
Ovina
Deer
Cervina
Musk animals
Moschida
Lamas
Auchenida
Goats
Caprina
Primæval giraffes
Sivatherida
Ancient camels
Procamelida
Pliohippus
Antelopes
Antilopina
Deer-like animals
Elaphida
Primæval camels
Pöebrotherida
Protohippus
Hollow-horned
Cavicornia
Camel-shaped
Tylopoda
Tragulida
Miohippus
Primæval deer
Dremotherida
Oreodontia
Mesohippus
Tapirs
Tapirida
Elephants
Mastodontida
Orohippus
Lamatapire
Macrauchenida
Xiphodontia
Dino-
therida
Dinocerata
River-horses
Obesa
Swine
Setigera
Eohippus
Rhinoceros-
horse
Elasmotherida
Hyopo-
tamida
Rhinoceros
Nasicornia
Hyracotherium
Primæval horse
Bronto-
therida
Primary swine
Anthraco-
therida
Proboscidæ
Primary
ruminants
Prorumi-
nantia
Palæo-
therida
Primary Pair-hoofed
Anaplotherida
......?......
Primary Odd-hoofed
animals
Coryphodontia
Flat-hoofed
Hyracea
Periptychida
Phenacontida
Condylarthra

divided into two sub-orders—the Pig-shaped and the Cud-chewing or Ruminating animals. The Pig-shaped (*Chœromorpha,* also called Tuberculate-toothed animals, *Bunodentia*) comprise in the first place the other branch of the Primary Hoofed animals, the Anoplotherida, which we consider the common primary form of all Pair-hoofed animals, or Artiodactyla (*Dichobune,* etc.). Out of the Anoplotherida arose, as two diverging branches, the primæval Swine, or *Anthracotheria,* on the one hand, forming the transition to the swine and river-horses, and the Primary Ruminants (*Proruminantia*) on the other, forming the transition to the Ruminants or crescentic-toothed animals (*Selenodontia*). The Hyopotamida and Xiphodontia are the oldest Ruminants (*Ruminantia*); to them belong, in the first place, the Primary Deer, or Dremotherida, to which, among living animals, the Tragulida are most closely allied, and out of which perhaps the Deer-shaped animals (*Elaphia*) and the Hollow-horned (*Cavicornia*) arose as two diverging branches. A peculiar lateral branch of the Deer-tribe is formed by the Giraffes. The pedigree of the Cavicornia is very perfectly known. Out of the primary group of Antelopes were developed, on the one hand, the Goats and the closely related Sheep; on the other, the Oxen. A very peculiar side-branch, that branched off from the root of the Ruminant tribe, is formed by the Camel-shaped animals (Tylopoda), and their pedigree can be traced upwards step by step from the Pöebrotheria as clearly as that of the Horses. The accompanying systematic survey on p. 352 and the corresponding pedigree on p. 353 will show how the numerous families of Hoof-animals are grouped according to the genealogical hypothesis.

Another very remarkable order of Hoofed animals is formed by the Elephants and a number of kindred extinct colossal animals. They are generally called *Trunked animals* (*Proboscidea*), because most of them possess a long proboscis. The root of this order is probably also among the Coryphodonts, and further back among their ancestors, the Phenacodonts. The limbs of all these Trunked animals exhibit an essentially different development from that of the long-fingered Pair-toed and Odd-toed animals, which possess short upper legs. In the Trunked animals, on the contrary, the upper legs are long; the feet, however, short, generally with five equally developed short toes. Our present elephants, which stand so isolated in our day, are descended from extinct (Miocene) Mastodons. Another branch is formed by the remarkable Dinotherida. Probably this order also includes the gigantic Dinocerata, elephant-like animals of North America, which carried three pairs of huge horns on their heavy head.

We know very little about the ancestors and relations of the last order of Hoofed animals, the Flat-hoofed (*Hyracea* or *Lamnungia*). These small, closely haired, rabbit-like Ungulata resemble the Primary Hoofed animals in construction of the skeleton, the Tapirs as regards the formation of foot, and the Rhinoceroses in the formation of their molars. By the absence of canine teeth and by their chisel-shaped incisors, they are allied to the Rodents. Like the Trunked animals, the Flat-hoofed animals are closely allied to the Rodentia, and may be regarded as descendants of the ancient Placental group, out of which the Hoofed animals developed on the one hand, and the Rodents on the other.

The legion of the Gnawing animals (*Rodentia*) forms at present by far the most extensive group of mammals, both as regards the number of living species and genera, and the number of individuals. However, all the living Rodents differ very little in the essential internal structure, and appear only to be multifarious varieties of one and the same type. The dentition, more especially, exhibits everywhere the same characteristic form: above and below one pair of chisel-shaped, rootless incisors, specially adapted for gnawing the hard portions of plants; behind these incisors, and separated by a great interspace in the dentition, are a few large molars with enamel folds; there are no canine teeth. A form of dentition similar to that of our present living Glirina, or Cutting Rodents, is also possessed by two interesting extinct orders of the Rodentia, the Tillotherida (Tillodontia) and the Toxotherida (Toxodontia). The Tillodontia, fossilized in the Eocene of North America, were of the form of body and the size of tapirs; the Toxodontia, fossilized in the Diluvium of South America, were more like a rhinoceros. Both orders combined the characteristics of our present Rodents (Glirina), of the Hoofed animals (Condylarthra), and of the Edentata. We may, therefore, regard them as root offshoots of the same ancient Placental tribe, out of which the Hoof-animals arose on the one side, and the Rodents on the other.

In the same way as we can trace back these large main groups of Herbivorous Placentalia to a common, ancient primary form belonging probably to the Chalk period, we find this also possible as regards the large group of the Carnivorous Placentalia, or the Beasts of Prey in the wider sense (*Carnassia*). We comprise in this great legion

four closely related orders—the ancient and long since extinct Primæval Rapacious animals (Creodonta), the small Insect-eaters (Insectivora), the large flesh-eaters (Carnivora), and the Rapacious sea-animals (Pinnipedia). Of these four legions, the first must be considered the common primary group, out of which the three latter gradually became developed.

The primary order of Primæval Rapacious Animals (*Creodonta*) has recently become much better known owing to the numerous Eocene species found both in Europe and North America. They were discovered principally by Cope and Filhol, and divided into five different families. Some of these, the primæval bear-dogs (Arctocyonida), are closely allied to the rapacious marsupials (Creophaga, see p. 336); others (Leptictida) pass over into our present insect-eaters (the hedgehogs, Centetida); others again (*e.g.* the Synoplotherida, of the size of a bear) appear closely allied to the earliest Carnivora (Bears). As a rule, all of these Creodonta are distinguished by a weak expression of the character of beasts of prey, whereas, on the other hand, they stand very close both to the primary group of flesh-eating Marsupials, as well as to the earliest primary forms of the Hoofed animals and the Rodents. They agree, therefore, completely with the phylogenetic suppositions which we raise for the very ancient, common primary group of all the Creodonta. These Creodonta were unwieldy creatures that walked on the sole of their five-toed flat feet, and had the full typical dentition of Placental animals (see p. 343); the forty-four teeth were much less differentiated than in the case of the other Carnassia.

The order of Insect-eaters (*Insectivora*) is next akin to

the common extinct primary group of the Creodonta, and has retained from these, by inheritance, many of the lower features of organization. They appear, phylogenetically, the oldest of all the present living beasts of prey; the hedgehog, especially, has faithfully retained many characteristics of the lower and original form of organization. The shrew-mice and moles also remain at a very low stage. All walk on the soles of their five-toed flat feet, and most of them are characterized by the full dentition of Placental animals, with small canines and numerous pointed, tuberculated molars.

The order of actual Flesh-eaters (*Carnivora*), or land animals of prey in a narrower sense, presents a much greater variety of forms. In them the typical dentition of the Rapacious animals differentiates in a very characteristic manner, inasmuch as the four large canines, and behind these four peculiar teeth for tearing (the carnassial or flesh-tooth), one on either side of the jaw above and below, are strongly developed. This flesh-tooth is a peculiarly developed molar, the large and sharp and generally jagged crown of which is specially adapted for tearing flesh. The more the rapacious character is purely developed (principally in the cats that stand highest), the larger, in proportion, are the canines and the carnassial teeth, and the weaker the other teeth. And conversely, the less the carnivorous character is expressed, the less are those eight principal teeth differentiated, and the more equal are all the teeth; this is notably the case with the Bear-family, which is closely allied to the primary group of the Creodonta. The different families of our present Carnivora have developed out of an ancient, common primary group which stood

midway between the Bears, Dogs, and Viverræ; numerous Tertiary fossils explain the history of the tribe. The transformation of the five-toed feet went hand in hand with the differentiation of the dentition; the more rapid the movement of the Carnivora, the slimmer became their legs and the smaller their feet. The Viverræ (which use only the half of their soles) developed out of the older Bears (which use the whole sole), and out of the Viverræ again arose those animals which walk on their toes only (dogs and cats).

The fourth and last order, that of the Marine animals of prey, or Seals (*Pinnipedia*), have differentiated furthest from the tribe of Rapacious animals. They comprise sea-bears, sea-lions, sea-dogs, and the walruses as a peculiar side-line. Although the marine animals of prey appear externally very unlike land animals of prey, they are nevertheless nearly akin to them, in their internal structure, their dentition, and their peculiar, girdle-shaped placenta, and have evidently descended from the same stock. Their earliest ancestors must be looked for among the Creodonta, their latest perhaps among the weasel species (*Mustelina*). Even at the present day the fish-otters (*Lutra*), and still more so the sea-otters (*Enhydris*), present a direct form of transition to seals, and clearly show how the bodies of land Carnivora are transformed into the shape of a seal by adaptation to an aquatic life, and how the steering-fins of marine rapacious animals have arisen out of the legs of the former. In like manner their dentition has become peculiarly transformed owing to their having adapted themselves to fish as a food.

The last and most highly developed group of Placental animals, the legion of Highest Animals, or *Primates*, stands

at the head of all the Mammalia, and hence of the whole animal kingdom generally. Under this name even Linnæus, more than a hundred years ago, comprised the four groups of the Bats, Semi-apes, Apes, and Men ("Vespertilio, Lemur, Simia, Homo"). All four orders agree in a number of special anatomical characteristics by which they differ from all other Placental animals. From this we infer that all Primates are derived from one and the same stock, and that its root must probably be looked for among Creodonta, the same primæval group of Placentalia out of which the Rapacious animals have developed. And the living Insectivora, as the earliest order of them, still show various close relationships to the Primates, more especially to the Bats (*Chiroptera*) and to the Semi-apes (*Prosimiæ*). On the other hand, these latter appear closely allied to the Apes (*Simiæ*), out of which tribe Men (*Anthropi*) developed as early as the Tertiary period.

The *Semi-apes* (*Prosimiæ*), or *Lemurs* (*Lemurina*), were formerly generally classed in one and the same group with Apes, and, by Blumenbach, were termed the Quadrumana, or Four-handed animals. However, in my "General Morphology," already in 1866, I separated them from the latter, not only because they differed far more from all apes than the most different apes among one another, but also because the group contains some of the most interesting transition-forms leading to the other orders of the Primates. I infer from this that the few still living Semi-apes, which, moreover, differ very much among one another, represent the last surviving remnant of an almost extinct primary group which was once rich in forms, out of which a large portion of the higher Placentalia developed as diverging

branches. The ancient primary group of Semi-apes probably developed out of the Creodonta, or from the still older "Proplacentalia;" perhaps, however, directly out of the ancestors of the ape-footed Marsupials (Pedimana), which are remarkably like them in the transformation of the hind foot into a hand for grasping. The very ancient primary forms (which probably originated during the Chalk period) have, of course, long since been extinct, like most of the other transition-forms between them and the other orders of Placentalia. However, several remnants of the latter order have been preserved in the still living Semi-apes. Among these, the remarkable Ay-Ay of Madagascar (*Chiromys madagascariensis*) constitutes the remnant of the group of the Leptodactyla and the transition to Rodents. The strange flying lemur of the South Sea and Sunda Islands (*Galeopithecus*), the only remnant of the group of *Pteropleura*, forms a perfect intermediate stage between Semi-apes and Bats. The long-footed Semi-apes (*Tarsius, Otolicnus*) constitute the last remnant of that primary branch (*Macrotarsi*) out of which the Insectivora developed. The short-footed forms (*Brachytarsi*) are the medium of connection between them and genuine Apes. The Short-footed Semi-apes comprise the long-tailed Makis (*Lemur*), the short-tailed Indris (*Lichanotus*), and the Loris (*Stenops*), the latter of which seems to be very closely allied to the probable ancestors of man among the Semi-apes. The short-footed as well as the long-footed Prosimiæ live widely distributed over the islands of Southern Asia and Africa, more especially in Madagascar; some live also on the continent of Africa. They all lead a solitary, nocturnal kind of life, and climb about on trees.

The curious order of Flying mammals, or Bats (*Chiroptera*), is nearly allied to the Semi-apes. It has become strikingly transformed by adaptation to a flying mode of life, just as the marine animals of prey have become modified by adaptation to a swimming mode of life. This order probably also originated out of the Semi-apes, with which it is even at present closely allied through the flying lemurs (*Galeopithecus*). The formation of the flying membrane, which stretches out between the trunk of the body and the extremity of the limbs, attains its greatest perfection in this order of mammals; beginnings of this membrane are, however, also met with in other orders, as, for instance, among the flying marsupials and the flying squirrels. Of the two orders of flying animals, the insect-eating forms, or Flying Mice (*Nycterides*), are probably the older branch; and subsequently out of the latter arose the fruit-eaters, or Flying Foxes (*Pterocynes*).

We have now, finally, to mention the last order of mammals, the genuine Apes (*Simiæ*), but as, according to the zoological system, the human race belongs to this order, and as it undoubtedly developed historically out of a branch of this order, we shall devote a special chapter to a more careful examination of its pedigree and history. The records which historically establish the much-discussed Descent of Men from Apes, are precisely the same as in every other portion of the history of development, namely, the testimonies of comparative anatomy, ontogeny, and palæontology. These authentic records, however, express themselves in a far more intelligible and a much less equivocal language in this most important chapter of phylogeny than in many others of our scientific inquiry.

CHAPTER XXVII.

HISTORY AND PEDIGREE OF MAN.

The Application of the Theory of Descent to Man.—Its Immense Importance and Logical Necessity.—Man's Position in the Natural System of Animals, among Disco-placental Animals.—Incorrect Separation of the Bimana and Quadrumana.—Correct Separation of Semi-apes from Apes.—Man's Position in the Order of Apes.—Narrow-nosed Apes (of the Old World) and Flat-nosed Apes (of America).—Difference of the Two Groups.—Phylogenetic Reduction of the Dentition.—Origin of Man from Narrow-nosed Apes.—Human Apes, or Anthropoidea.—African Human Apes (Gorilla and Chimpanzee).—Asiatic Human Apes (Orang and Gibbon).—Comparison between the Different Human Apes and the Different Races of Men.—Fossil Remains of Apes.—Survey of the Series of the Progenitors of Man (in Twenty-five Stages).—Invertebrate Progenitors (Nine Stages) and Vertebrate Progenitors (Sixteen Stages).

Of all the individual questions answered by the Theory of Descent, of all the special inferences drawn from it, there is none of such importance as the application of this doctrine to Man himself. As I remarked at the beginning of this treatise, the inexorable necessity of the strictest logic forces us to draw the special deductive conclusion from the general inductive law of the theory, that Man has developed gradually, and step by step, out of the lower Vertebrata, and more immediately out of Ape-like Mammals. That this doctrine is an inseparable part of the Theory of Descent, and hence also of the universal Theory of Development in general, is recognized by all thoughtful adherents

of the theory, as well as by all its opponents who reason logically.

But if the doctrine be true, then the recognition of the animal origin and pedigree of the human race will necessarily affect, more deeply than any other progress of the human mind, the views we form of all human relations, and the aims of all human science. It must sooner or later produce a complete revolution in the conception entertained by man of the entire universe. I am firmly convinced that in future this immense advance in our knowledge will be regarded as the beginning of a new period of the development of Mankind. It can only be compared to the discovery made by Copernicus, who was the first who ventured distinctly to express the opinion, that it was not the sun which moved round the earth, but the earth round the sun. Just as the *geocentric conception* of the universe—namely, the false opinion that the earth was the centre of the universe, and that all its other portions revolved round the earth—was overthrown by the system of the universe established by Copernicus and his followers, so the *anthropocentric conception* of the universe—the vain delusion that Man is the centre of terrestrial nature, and that its whole aim is merely to serve him—is overthrown by the application (attempted long since by Lamarck) of the theory of descent to Man. As Copernicus' system of the universe was mechanically established by Newton's theory of gravitation, we see Lamarck's theory of descent attain its causal establishment by Darwin's theory of selection. This comparison, which is very instructive in many respects, I have discussed more fully in my work "On the Origin and Pedigree of the Human Race."

In order to carry out this extremely important application of the Theory of Descent to man, with the necessary impartiality and objectivity, I must above all beg the reader (at least for a short time) to lay aside all traditional and customary ideas on the "Creation of Man," and to divest himself of the deep-rooted prejudices concerning it, which are implanted in the mind in earliest youth. If he fail to do this, he cannot objectively estimate the weight of the scientific arguments which I shall bring forward in favour of the animal derivation of Man, that is, of his origin out of Ape-like Mammals. We cannot here do better than imagine ourselves with Huxley to be the inhabitants of another planet, who, taking the opportunity of a scientific journey through the universe, have arrived upon the earth and have there met with a peculiar two-legged mammal called Man, diffused over the whole earth in great numbers. In order to examine him zoologically, we should pack a number of the individuals of different ages and from different lands (as we should do with the other animals collected on the earth) into large vessels filled with spirits of wine, and on our return to our own planet we should commence the comparative anatomy of all these terrestrial animals quite objectively. As we should have no personal interest in Man, in a creature so entirely different from ourselves, we should examine and criticize him as impartially and objectively as we should the other terrestrial animals. In doing this we should, of course, in the first place refrain from all conjectures and speculations on the nature of his soul, or on the spiritual side of his nature, as it is usually called. We should occupy ourselves solely with his bodily structure, and with that natural

conception of it which is offered by the history of his individual development.

It is evident that in order correctly to determine Man's position among the other terrestrial organisms we must, in the first place, follow the guidance of the natural system. We must endeavour to determine the position which belongs to Man in the natural system of animals as accurately and distinctly as possible. We shall then, if in fact the theory of descent be correct, be able from his position in the system to determine the real primary relationship, and the degree of consanguinity connecting Man with the animals most like him. The hypothetical pedigree of the human race will then follow naturally as the final result of this anatomical and systematic inquiry.

Now if, by means of comparative anatomy and ontogeny, we seek for man's position in that Natural System of animals which formed the subject of our last chapters, the incontrovertible fact will at once present itself to us that man belongs to the tribe, or phylum, of the Vertebrata. Every one of the characteristics, which so strikingly distinguish all the Vertebrata from all Invertebrata, is possessed by him. It has also never been doubted that of all the Vertebrata the Mammals are most closely allied to Man, and that he possesses all the characteristic features distinguishing them from all other Vertebrata. If next we further carefully examine the three different main groups or sub-classes of Mammals—the inter-connections of which were discussed in our last chapter—there cannot be the slightest doubt that Man belongs to the Placentals, and shares with all other Placentals the important characteristics which distinguish them from Marsupials and from

Cloacals.—The sub-class of Placentals, with its wealth of forms, we subdivided into six large main groups or legions; the last of these we named the legion of the Leading animals, Primates, because it included Men and Apes, and, moreover, their nearest relatives, the Semi-apes and Bats. The close consanguinity between these orders, which induced the clear-sighted zoologist Linnæus, a hundred and fifty years ago, to group them together as Primates, appears firmly established by important peculiarities in the structure of their bodies and in their development, more especially by the peculiar nature of their disc-shaped deciduate placenta (Discoplacentalia). But, as every one knows, of all the different orders of Primates, that of the Apes stands far nearer to Man in every bodily feature than any of the others. Hence the only remaining question now is, whether, in the system of animals, Man is to be directly classed in the order of genuine Apes, or whether he is to be considered as the representative of a special order of Primates.

The interpretation of Linnæus' order of Primates was first undertaken by Blumenbach, of Göttingen; he separated Man as a special order, under the name of *Bimana*, or two-handed, and contrasted him with the Apes and Semi-apes under the name of *Quadrumana*, or four-handed. This classification was also adopted by Cuvier and, consequently, by most subsequent zoologists. It was not until 1863 that Huxley, in his excellent work, "The Evidence as to Man's Place in Nature,"[27] showed that this classification was based upon erroneous ideas, and that the so-called "four-handed" Apes and Semi-apes are "two-handed" as much as man is himself. The difference between the foot and hand does not consist in the *physiological* peculiarity that the

first digit or thumb is opposable to the four other digits or fingers in the hand, and not in the foot; for there are wild tribes of men who can oppose the first or large toe to the other four, just as if it were a thumb. They can, therefore, use their "grasping foot" like a so-called "hinder hand," as do Apes. The Chinese boatmen row with this hinder hand, the Bengal workmen weave with it. The Negro, in whom the big toe is especially strong and freely movable, when climbing seizes hold of the branches of the trees with it, just like the "four-handed" Apes. Nay, even the newly born children of the most highly developed races of men, during the first months of their life, grasp as easily with the "hinder hand" as with the "fore hand," and hold a spoon placed in its clutch as firmly with their big toe as with the thumb! On the other hand, among the higher Apes, especially the gorilla, hand and foot are differentiated as in man (compare Plate IV.).

The essential difference between hand and foot is, therefore, not physiological, but *morphological*, and is determined by the characteristic structure of the bony skeleton and of the muscles attached to it. The ankle-bones differ essentially from the wrist-bones in arrangement, and the foot possesses three special muscles not existing in the hand (a short flexor muscle, a short extensor muscle, and a long fibular muscle). In all these respects, Apes and Semi-apes entirely agree with man, and hence it was quite erroneous to separate him from them as a special order on account of the stronger differentiation of his hand and foot. It is the same also with all the other structural features by means of which it was attempted to distinguish Man from Apes; for example, the relative length of the limbs, the structure of

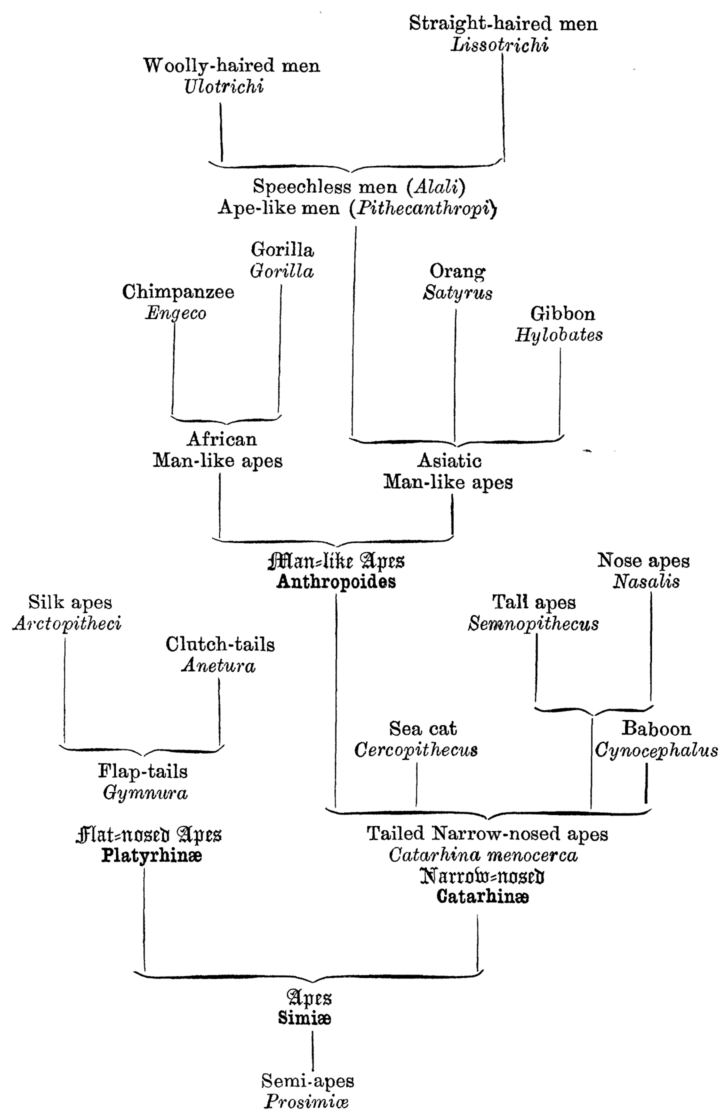
the skull, of the brain, etc. In all these respects, without exception, the differences between Man and the higher Apes are less than the corresponding differences between the higher and the lower Apes. Hence Huxley, for reasons based on the most careful and most accurate anatomical comparisons, arrives at the extremely important conclusion: "Thus, whatever system of organs be studied, the comparison of their modifications in the Ape series leads to one and the same result, viz. that the structural differences which separate Man from the Gorilla and Chimpanzee are not so great as those which separate the Gorilla from the lower Apes." In accordance with this, Huxley, strictly following the demands of logic, classes Man, Apes, and Semi-apes in a single order, *Primates*, and divides it into the following seven families, which are of almost equal systematic value: (1) Anthropini (Man); (2) Catarhini (genuine Apes of the Old World); (3) Platyrhini (genuine American Apes); (4) Arctopithecini (American clawed Apes); (5) Lemurini (short-footed and long-footed Semi-apes); (6) Chiromyini; (7) Galeopithecini (Flying Lemurs). (Compare Chapter XXVI.)

— If we wish to arrive at a natural system, and consequently at the pedigree of the Primates, we must go a step further still, and entirely separate the Semi-apes, or Prosimiæ (Huxley's last three families), from Genuine Apes, or Simiæ (the first four families). For, as I have already shown in my "General Morphology," the Semi-apes differ in many and important respects from Genuine Apes, and in their individual forms are more closely allied to the various other orders of Discoplacentalia. They stand closest to the Insectivora, and have probably, with the latter, to be de-

SYSTEMATIC SURVEY

Of the Families and Genera of Apes.

Sections of Apes.	*Families of Apes.*	*Genera of Apes.*	*Systematic Name of the Genera.*
I. APES OF THE NEW WORLD (Hesperopitheca), OR FLAT-NOSED APES (Platyrhinæ).			
A. Platyrhini with claws. **Arctopitheci.**	I. Silky apes *Hapalida*	1. Brush ape. 2. Lion ape.	1. Midas. 2. Jacchus.
B. Platyrhini with blunt nails. **Dysmopitheci.**	II. Flat-nosed, without prehensile tail *Gymnura* or *Aphyocerca*	3. Squirrel ape. 4. Leaping ape. 5. Nocturnal ape. 6. Tail ape.	3. Chrysothrix. 4. Callithrix. 5. Nyctipithecus. 6. Pithecia.
	III. Flat-nosed, with prehensile tail *Anetura*, or *Labidocerca*	7. Rolling ape. 8. Climbing ape. 9. Woolly ape. 10. Howling ape.	7. Cebus. 8. Ateles. 9. Lagothrix. 10. Mycetes.
II. APES OF THE OLD WORLD (Heopitheca), OR NARROW-NOSED APES (Catarhinæ).			
C. Dog-headed or Tailed Catarhini. **Cynopitheca** or **Menocerca.**	IV. Tailed Catarhinæ, with cheek-pouches *Ascoparea*	11. Baboon. 12. Macaque. 13. Sea cat.	11. Cynocephalus. 12. Inuus. 13. Cercopithecus.
	V. Tailed Catarhini, without cheek-pouches *Anasca*	14. Holy ape. 15. Short ape. 16. Nose-ape.	14. Semnopithecus. 15. Colobus. 16. Nasalis.
D. Man-headed or Tail-less Catarhini. **Anthropomorpha** or **Lipocerca.**	VI. Tail-less human apes *Anthropoides*	17. Gibbon. 18. Orang-Outan. 19. Chimpanzee. 20. Gorilla.	17. Hylobates. 18. Satyrus. 19. Troglodytes. 20. Gorilla.
	VII. Men *Anthropini*	21. Ape-like man, or speechless man. 22. Talking man.	21. Pithecanthropus (Alalus). 22. Homo.


Straight-haired men
Lissotrichi
Woolly-haired men
Ulotrichi
Speechless men (Alali)
Ape-like men (Pithecanthropi)
Gorilla
Gorilla
Chimpanzee
Engeco
Orang
Satyrus
Gibbon
Hylobates
African
Man-like apes
Asiatic
Man-like apes
Man-like Apes
Anthropoides
Nose apes
Nasalis
Silk apes
Arctopitheci
Tall apes
Semnopithecus
Clutch-tails
Anetura
Sea cat
Cercopithecus
Baboon
Cynocephalus
Flap-tails
Gymnura
Flat-nosed Apes
Platyrhinæ
Tailed Narrow-nosed apes
Catarhina menocerca
Narrow-nosed
Catarhinæ
Apes
Simiæ
Semi-apes
Prosimiæ

rived from the ancient Eocene primary group of Creodonta. On the other hand, the Semi-apes must probably be considered as the remnants of the common primary group, out of which the other orders of Primates have developed as two diverging branches. But man cannot, either anatomically or phylogenetically, be separated from the order of Genuine Apes, or Simiæ, as he is in every respect more closely allied to the higher Genuine Apes than the latter are to the lower Genuine Apes.

Genuine Apes (*Simiæ*) are universally divided into two perfectly natural groups, namely, the Apes of the New World, or American Apes, and the Apes of the Old World, which are indigenous to Asia and Africa, and which formerly also existed in Europe. These two classes differ principally in the formation of the nose, and they have been named accordingly. American Apes have flat noses, so that the nostrils are in front, not below; hence they are called Flat Noses (*Platyrhinæ*). On the other hand, the Apes of the Old World have a narrow cartilaginous bridge, and the nostrils turned downwards, as in man; they are, therefore, called Narrow Noses (*Catarhinæ*). Further, the jaw, which plays an important part in the classification of Mammals, is essentially distinct in these two groups. All Catarhinæ, or Apes of the Old World, have exactly the same dentition as Man, namely, in each jaw four incisors above and below, then on each side a canine tooth and five cheek-teeth, of which two are pre-molars and three molars, altogether thirty-two teeth. But all Apes of the New World, all Platyrhinæ, have four more cheek-teeth, namely, three pre-molars and three molars on each side, above and below: they consequently possess thirty-six teeth. Only one small

group forms an exception to this rule, namely, the *Arcto-pitheci*, or *Clawed Apes*, in whom the third molar has degenerated, and they accordingly have on each half of their jaw three pre-molars and two molars. They also differ from the other Platyrhinæ by having claws on the fingers of their hands and the toes of their feet, not nails like Man and the other Apes. This small group of South American Apes, which includes among others the well-known pretty little Midas-monkey and the Jacchus, must probably be considered only as a peculiarly developed lateral branch of the Platyrhinæ, which has lost one molar on either side of the jaw above and below.

Now, if we ask what evidence can be drawn, as to the pedigree of Apes, from the above facts, we must conclude that all the Apes of the New World have developed out of one tribe, for they all possess the characteristic dentition and the nasal formation of the Platyrhinæ. In like manner it follows that all the Apes of the Old World must be derived from one and the same common primary form, which possessed the same formation of nose and dentition as all the still living Catarhinæ. Further, it is very probable that both of these tribes of Apes are derived from a common, ancient primary group, and that this group must be looked for among the Semi-apes, the lemurs. The comparative morphology of the Placental dentition—which has recently been admirably described by Baume, a Berlin dentist, in his suggestive "Odontological Investigations" (1882)—here also again serves as the safest guide. We may with certainty infer, from the structure and development of the dentition in Primates, that all of these Highest animals, Men, Apes, and also Semi-apes, were originally descended from an earlier Eocene

primary form, which possessed the full typical Placental jaw of 44 teeth, namely, on either side of the jaw, above and below, 11 teeth: 3 incisors, 1 canine, 4 pre-molars, 3 molars = $\frac{3.1.4.3}{3.1.4.3}$ (compare above, p. 341). By 1 incisor and 1 pre-molar being lost by degeneration, there arose the form of dentition possessed by the Platyrhini: $\frac{2.1.3.3}{2.1.3.3} = 36$. Out of this *primary* dentition of Apes there arose that of the Arctopitheci by the loss of a molar, that of the Catarhini by loss of a pre-molar, the former with 2.1.3.2, the latter with 2.1.2.3 teeth in either side of the jaw above and below. According to this it might be inferred that the Platyrhinæ (and especially the Gymnura, Chrysothrix, etc.) were the most ancient group among the still living Apes, the remains of the primary group out of which the other Apes developed as diverging branches. However, other reasons favour the opinion of later zoologists, according to whom the two tribes of Apes have developed independently of each other in the two hemispheres out of Semi-apes.

But whether this latter diphyletic descent of Apes or the above monophyletic descent be considered the more probable, we are led, from their comparative morphology, to the exceedingly important conclusion—which is of the utmost significance in regard to Man's distribution on the earth's surface—that Man *has developed out of the Catarhinæ.* For we cannot discover a zoological character distinguishing him in a higher degree from the allied Apes of the Old World than that in which the most divergent forms of this group are distinguished from one another. This is the important result of Huxley's careful anatomical examination of the question, and it cannot be too highly estimated. The anatomical differences between

Man and the most man-like Catarhinæ (Orang, Gorilla, Chimpanzee) are in every respect less than the anatomical differences between the latter and the lowest stages of Catarhinæ, more especially the Dog-like Baboon. This exceedingly important conclusion is the result of an impartial anatomical comparison of the different forms of Catarhinæ.

If, therefore, we recognize the natural system of animals as the guide to our speculations, and establish upon it our pedigree, we must necessarily come to the conclusion that *the human race is a small branch of the group of Catarhinæ, and has developed out of long since extinct Apes of this group in the Old World.* Some adherents of the Theory of Descent have thought that the American races of Men have developed, independently of those of the Old World, out of American Apes. I consider this hypothesis to be quite erroneous, for the complete agreement of all mankind with the Catarhinæ, in regard to the characteristic formation of the nose and dentition, distinctly proves that they are of the same origin, and that they developed out of a common root after the Platyrhini or American Apes had already branched off from them. The primæval inhabitants of America, as is proved by numerous ethnographical facts, immigrated from Asia, and partly perhaps from Polynesia (or even from Europe).

There still exist great difficulties in establishing an accurate pedigree of the Human Race; we can only further assert, that the nearest progenitors of man were "man-headed apes," or Anthropoides, also called tail-less Catarhinæ (*Lipocerca*), similar to (but not exactly like) the still living Man-like Apes. These evidently developed pretty late out of the Cynopitheci, or "dog-headed apes," or tailed Catarhinæ

(*Menocerca*), the original form of Ape. Of those tail-less Catarhinæ, which are now frequently called Man-like Apes, or Anthropoides, there still exist four different genera containing about a dozen different species.

The largest Man-like Ape is the famous Gorilla (called *Gorilla engena*, or *Troglodytes gorilla*), which is indigenous to the tropics of Western Africa, and was first discovered by the missionary, Dr. Savage, in 1847, on the banks of the river Gaboon. Its nearest relative is the Chimpanzee (*Troglodytes niger*, or *Pongo troglodytes*), also indigenous to Western Africa, but considerably smaller than the Gorilla, which surpasses man in size and strength. The third of the three large Man-like Apes is the Orang, or Orang-Outang, indigenous to Borneo and the other Sunda Islands, of which two kindred species have recently been distinguished, namely, the large Orang (*Satyrus orang*, or *Pithecus satyrus*) and the small Orang (*Satyrus morio*, or *Pithecus morio*). Lastly, there also exists in Southern Asia the genus *Gibbon* (Hylobates), of which from four to eight different species are distinguished. They are considerably smaller than the three first-named Anthropoides, and in most characteristics differ more from Man.

The tail-less Man-like Apes—especially since we have become more intimately acquainted with the Gorilla, and its connection with Man by the application of the Theory of Descent—have excited such universal interest, and called forth such a flood of writings, that there is no occasion for me here to enter into any detail about them. The reader will find their relations to Man fully discussed in the excellent works of Huxley,[27] Carl Vogt, and Büchner,[43] but best of all in Robert Hartmann's work on "The Anthropoid

Apes and their Organization as compared with the Human Organization" (1883). This anatomist gives even a clearer expression of the close blood-relationship, inasmuch as he separates the Primates into two families: (1) *Primarii* (Man and the Anthropomorphi); (2) *Genuine Apes* (*Catarhinæ* and *Platyrhinæ*). The most important general conclusion arrived at from these most careful comparisons is, that each one of the four Man-like Apes stands nearer to Man in one or several respects than the rest, but that no one of them can in every respect be called absolutely the most like Man. The Orang stands nearest to Man in regard to the formation of the brain, the Chimpanzee in important characteristics in the formation of the skull, the Gorilla in the development of the feet and hands, and, lastly, the Gibbon in the formation of the thorax.

Thus, from a careful examination of the comparative anatomy of the Anthropoides, we obtain a similar result to that obtained by Weisbach, from a statistical classification and a thoughtful comparison of the very numerous and careful measurements which Scherzer and Schwarz made of the different races of Men during their voyage round the earth in the Austrian frigate Novara. Weisbach comprises the final result of his investigations in the following words: "*The ape-like characteristics of Man* are by no means concentrated in one or another race, but are distributed in particular parts of the body, among the different races, in such a manner that each is endowed with some heirloom of this relationship—one race more so, another less, and even we Europeans cannot claim to be entirely free from evidences of this relationship." *

* Weisbach, "Novara-Reise," Anthropolog. Theil.

I must here also point out, what in fact is self-evident, that not one of all the still living Apes, and consequently not one of the so-called Man-like Apes, can be the progenitor of the Human Race. This opinion, in fact, has never been maintained by thoughtful adherents of the Theory of Descent, but it has been assigned to them by their thoughtless opponents. The Ape-like progenitors of the Human Race are long since extinct. We may possibly still find their fossil bones in the tertiary rocks of Southern Asia or Africa. In any case they will, in the zoological system, have to be classed in the group of tail-less Narrow-nosed Apes (*Catarhina Lipocerca*), or Anthropoides.

Of fossil remains of Apes we as yet, upon the whole, know but little, especially in comparison with the immense quantities of petrifactions of Rapacious animals and Hoof-animals, to which we owe many important inferences for the phylogeny of those legions of animals. The dearth of fossils from the order of Primates is easily accounted for from the peculiar mode of life and the distribution of these animals. Fortunately, it is counterbalanced by the exceedingly valuable and significant conclusions which we owe to the comparative anatomy and the ontogeny of this distinguished legion. Moreover, this much is already certain, that the order of Apes, during the Tertiary period, was represented by many extinct forms (as early as the Eocene and Miocene) even in Europe. Among these were large Men-apes (Dryopithecus Fontani, Pliopithecus antiquus), which showed greater proximity to Man in the formation of the jaw than any of the still living Anthropoids. Further palæontological discoveries will, it is to be hoped, soon give us further information of these "Anthropomorpha."

The genealogical hypotheses, to which we have thus far been led by the application of the Theory of Descent to Man, present themselves to every clearly and logically reasoning person as the direct results from the facts of comparative anatomy, ontogeny, and palæontology. Of course our phylogeny can indicate only in a very general way the outlines of the human pedigree. Phylogeny is the more in danger of becoming erroneous the more rigorously it is applied in detail to special animal forms known to us. However, we can, even now, with approximate certainty distinguish at least the following twenty-five stages of the ancestors of Man. Sixteen of these stages belong to the Vertebrata, and nine to the Invertebrate ancestors of Man.

THE CHAIN OF THE ANIMAL ANCESTORS, OR SERIES OF THE PROGENITORS, OF MAN.

(Comp. Ch. XXIV., XXVI.; Plates XVIII., XIX., and pp. 165, 281).

FIRST HALF OF THE SERIES OF THE ANCESTORS OF MAN.

INVERTEBRATE ANCESTORS OF MAN.

FIRST ANCESTRAL STAGE: **Primary Animals without Structure (Monera).**

The most ancient ancestors of Man, as of all other organisms, were living creatures of the simplest kind imaginable, organisms without organs, like the still living Monera. They consisted of simple, homogeneous, structureless and formless little lumps of mucous or albuminous matter (plasson), like the still living *Protamœba primitiva* (compare vol. i. p. 191, Fig. 1). The form-value of these most ancient ancestors of man was not even equal to that of a cell, but merely that of a cytod; for, as in the case of all Monera, the little lump of protoplasm did not as yet possess a cell-kernel. The first of these Monera originated in the beginning of the Laurentian period by spontaneous generation, or archigony, out of so-called "inorganic combinations," namely, out of simple combinations of carbon, oxygen, hydrogen, and nitrogen. The assumption of this spontaneous generation, that is, of a mechanical origin of the first organisms from inorganic matter, has been proved in our thirteenth chapter to be a necessary and justifiable hypothesis.

SECOND ANCESTRAL STAGE: **One-celled Primary Animals (Amœbina).**

The second ancestral stage of Man, as of all the higher animals and plants, is formed by a simple cell, that is, a little piece of protoplasm enclosing a kernel. There still exist large numbers of similar "single-celled organisms." Among them the common, simple Amœbæ (vol. i. p. 193, Fig. 2) cannot have been essentially different from these progenitors. The form-value of every Amœba is essentially the same as that still possessed by the egg of Man, and by the egg of all other animals (vol. i. p. 194, Fig. 3). The naked egg-cells of Sponges and Polyps (Plate VI., Fig. 6, 16), which creep about exactly like Amœbæ, cannot be distinguished from them. The egg-cell of Man, which like that of most other animals is surrounded by a membrane, resembles an enclosed Amœba. The first single-celled animals of this kind arose out of Monera by the differentiation of the inner kernel and the external protoplasm; they lived in the earliest Primordial period. An irrefutable proof that such single-celled primæval animals really existed as the direct ancestors of Man, is furnished according to the fundamental law of biogeny by the fact that the human egg is nothing more than a simple cell.

THIRD ANCESTRAL STAGE: **Cell-heaps (Moræada).**

In order to form an approximate conception of the organization of those ancestors of Man whch first developed out of the single-celled Primæval animals, it is necessary to trace the changes undergone by the human egg in the beginning of its individual development. It is just here that ontogeny guides us with the greatest certainty on to

the track of phylogeny. We have already seen that the egg of Man (in the same way as that of all other Mammals), after fructification has taken place, falls by self-division into a mass of simple and equi-formal cells (vol. i. p. 343, Fig. 6; vol. ii. p. 158, Fig. *C–E;* Plate V., Fig. 1–4, 11–14). All these divided globules are at first exactly like one another, naked cells containing a kernel, but without covering; in many animals they show movements like those of the Amœbæ. This ontogenetic stage of development which we called *Morula,* on account of its mulberry shape, is a certain proof that in the early primordial period there existed ancestors of man which possessed the form-value of a Cœnobium mass of homogeneous, loosely connected cells. They may be called a community of Amœbæ (Synamœbæ) or Mulberry-balls (Moræa). They originated out of the single-celled Primæval animals of the second stage by repeated self-division and by the permanent union of the products of this division.

FOURTH ANCESTRAL STAGE: **Ciliated Hollow Spheres (Blastæada).**

Out of the Morula, or Mulberry-ball, there develops, in the course of the ontogenesis of very many animals, a remarkable form of larva, which was first discovered by Bär, and termed by him the *germ-bladder,* or bladder of the germinal covering (Blastula, or Vesicula blastodermica, see p. 158, Fig. *F, G*). This is a hollow globule or ball filled with fluid, the thin walls of the globule consisting of a single layer of cells (the germinal membrane or blastoderm, Plate V., vol. i. p. 344, Fig. 6, 16). By the accumulation of the fluid, or Morula jelly, in the interior, the cells

are all pushed towards the periphery. In most of the lower animals—but likewise in the lowest Vertebrata (the Lancelet or Amphioxus)—this germinal form is called the ciliated bladder (Blastula or Blastosphæra), because the cells lying on the surface extend hair-like processes, or fringes of hairs, which by striking against the water keep the whole body rotating. In Man and in all other mammals, this Blastula does indeed still arise out of the Morula, but without cilia; these latter have become lost by adaptation. But this formation of the Blastodermic vesicle, which has in various instances been preserved by inheritance, points to a primæval form of a similar shape, which we may term a *ciliated hollow globule* (*Blastæa*). Our present "globular animalcules" (Volvocineæ and Catallacta, p. 86, Fig. 15) still give us an illustration of these "hollow-sphered ancestors." The Blastæa was a simple hollow globule filled with water or gelatinous substance, and the walls were formed of a single layer of ciliated cells. A certain proof of this is furnished by the Amphioxus, which is on the one hand related by blood to Man, but on the other has retained down to the present day the original stage of the Blastula.

FIFTH ANCESTRAL STAGE: **Primæval Stomach Animals (Gastræada).**

In the course of the individual development of Amphioxus, as well as in the most different lower animals, there first arises out of the Blastula the extremely important form of larva which we have named *stomach larva*, or *gastrula* (p. 158, *I*, *K*; Plate V., vol. i. p. 344, Fig. 8 and 18). In all other Metazoa there still exists a two-layered germinal form, which can be traced back to the gastrula. According

to the fundamental law of biogeny this gastrula proves the former existence of an independent form of primæval animal of the same structure, and this we have named the primæval stomach animal, or Gastræa. These Gastræada must have existed during the older Primordial period, and they must have also included the ancestors of man. A certain proof of this is furnished by the Amphioxus, which in spite of its blood-relationship to Man still passes through the stage of the gastrula with a simple intestine and a double intestinal wall (compare Plate XII., Fig. *B* 4).

SIXTH ANCESTRAL STAGE: **Flat Animals (Platoda).**

The human ancestors of the sixth stage which originated out of the Gastræada of the fifth stage, were Platoda of the simplest kind. These Platoda probably were most closely allied to the Gliding Worms, or Turbellaria, of all the still living Metazoa. They are already distinguished from their ancestors the Gastræada, externally, by possessing a bilateral fundamental form. Like the Turbellaria of the present day, the whole surface of their body was covered with cilia, and they possessed a simple body of an oval shape, entirely without appendages. These accœlomatous worms did not as yet possess a true body-cavity (cœlom), an anus, or blood. They originated in the early primordial period out of the Gastræada, by the formation of a middle germ-layer, or muscular layer, and also by the further differentiation of the internal parts into various organs; more especially the first formation of a nervous system, the simplest organs of sense, the simplest organs for secretion (kidneys) and generation (sexual organs). The proof that human ancestors existed of a similar formation, is to be

looked for in the circumstance that comparative anatomy and ontogeny point to bilateral Cœlenteria as the common primary form, not merely of all higher Worms, but also of the four higher tribes of animals. Now, of all the animals known to us, the Turbellaria (and, moreover, the simplest Rhabdocœla) are most closely allied to these primæval extinct Platoda (see Plate XIX., Fig. 12).

Seventh Ancestral Stage: **Cord Worms (Nemertina).**

The Platoda-ancestors of the last stage, which were probably represented during the Laurentian period by a long series of Turbellaria-forms gradually progressing onwards, are directly followed by the group of Cord-worms (Nemertina) as the seventh stage of our pedigree. In anatomical structure they appear still so closely allied to the Platoda, that they were formerly classed together with them. They are, however, essentially different from them in possessing an anus and the simplest system of blood-vessels, two most important arrangements, which are still wholly absent in the Cœlenteria. And they further show the first beginning of a body-cavity which distinguishes the Cœlomaria from the Cœlenteria. Many zoologists further find in the organization of the Nemertina —for instance, in the formation of the nervous system and intestine—the first indications of the subsequent Chordoniate structure. But apart from these perhaps important considerations, we have to regard simple Worm-like animals (Helminthes) as a necessary intermediate stage between the Platoda of the sixth stage and the Enteropneusta of the eighth. Of the still living Helminthes—the scanty remnant of a tribe with very many branches—the Nemertina and

the Ichthydina (Plate XIX., Fig. 13) appear to stand closest to that extinct intermediate stage.

EIGHTH ANCESTRAL STAGE: **Tongue Worms (Enteropneusta).**

Between the Nemertina of the seventh stage and the Prochordonia of the ninth stage, there probably existed, during the Laurentian period, a long series of Worm-like animals, which gradually led over from the simple organization of the former to the peculiar formation of the latter. The most important advance in their organization consisted in the formation of a branchial gut, in the change of a front part of the intestine into a characteristic "gill-basket with ciliated tract." This occurs among the Helminthes in one single living form of worm, the curious Acorn-worm (Balanoglossus). And as, in other respects, it shows agreements with the Chordonia, and differs from other worms, we may with great probability regard it as a last isolated remnant of that important intermediate group between the seventh and the ninth stage, the worms with branchial gut (Enteropneusta).

NINTH ANCESTRAL STAGE: **Animals with Primary Spinal Cord (Prochordonia).**

In our pedigree we must connect the stage of the Enteropneusta directly with that of the Prochordonia, or "animals with primary notochord," *i.e.* with the long since extinct common primary group of the Tunicates and Vertebrates. Among the still living Cœlomaria the curious Copelata (Appendicularia), as also the larvæ of the degenerated Ascidia, are the nearest relatives of these exceedingly remarkable Worms, which connect the widely differing classes of Invertebrate and Vertebrate animals.

That the ancestors of man really existed during the primordial period in the form of these Prochordonia, is distinctly proved by the exceedingly remarkable and important agreeement presented by the ontogeny of the Amphioxus and the Ascidia (compare Plates XII. and XIII.). From this fact the earlier existence of Chordonia may be inferred, which of all known Bilaterata were most closely related to the Appendiculariæ, and to the freely swimming young forms or larvæ of the simple Sea-squirts (Ascidia, Phallusia). They originated out of the Helminthes of the eighth stage by the formation of a dorsal nerve-marrow (medulla tube), and by the formation of the spinal rod (notochord) which lies below it. It is just the position of this central spinal rod, or axial skeleton, between the dorsal marrow on the dorsal side, and the intestinal canal on the ventral side, which is most characteristic for all Vertebrate animals, including man, but also for the primary forms of the Tunicates. The form-value of this ninth stage nearly corresponds with that which the larvæ of the simple Sea-squirts exhibit at the time when they show the beginning of the dorsal marrow and spinal rod (Plate XII., Fig. *A* 5, and Plate XIX., Fig. 19, 20; compare the explanation of these figures in the Appendix).

SECOND HALF OF THE SERIES OF HUMAN ANCESTORS.

VERTEBRATE ANIMAL ANCESTORS OF MAN.

(Vertebrata.)

TENTH ANCESTRAL STAGE: **Skull-less Animals (Acrania).**

The series of human ancestors, which in accordance with their whole organization we have to consider as Vertebrate animals, begins with the Skull-less animals, or Acrania, of whose nature the still living Lancelet (*Amphioxus lanceolatus,* Plate XII. *B*, XIII. *B*) gives us a faint idea. Since this little animal in its earliest embryonal state entirely agrees with the Ascidia, and in its further development shows itself to be a true Vertebrate animal, it forms a direct transition from the Vertebrata to the Invertebrata. Probably the human ancestors of the tenth stage in many respects differed from the Amphioxus—the last surviving and partially degenerated representative of the Skull-less animals—yet they must have resembled it in its most essential characteristics, in the absence of head, skull, and brain. The hypothetical Primary Vertebrates (Provertebrata) were skull-less animals of such structure, and out of them at a later date were developed the animals with skulls. They lived during the primordial period, and originated out of the non-articulated Prochordonia of the ninth stage by the formation of the metamera, or body segments, and also by the further differentiation of all organs. Probably the separation of the two sexes (gono-

chorism) also began at this stage, whereas all the previously mentioned invertebrate ancestors appear to have exhibited the condition of hermaphrodites (hermaphroditism). The *certain proof* of the former existence of these skull-less and brainless ancestors of man, is furnished by the comparative anatomy and the ontogeny of the Amphioxus and of the Craniota.

ELEVENTH ANCESTRAL STAGE: **Round-mouthed Animals (Cyclostoma).**

Out of the Skull-less ancestors of man there arose in the first place animals with skulls, or Craniota, of the most imperfect nature. The lowest stage of all still living Craniota is occupied by the class of round-mouthed animals, or Cyclostoma, namely, the Hag (Myxinoidea) and Lampreys (Petromyzontia). From the internal organization of these single-nostriled animals, or Monorhina, we can form an approximate idea of the nature of the human ancestors of the eleventh stage. In the former, as also in the latter, skull and brain must have been of the simplest form, and many important organs, as, for example, the swimming-bladder, the inner gill-arches, the jaw-skeleton, and both pairs of legs, may probably as yet not have existed. However, the pouch gills and the round sucking mouth of the Cyclostoma must probably be looked upon as purely adaptive characteristics, which did not exist in the corresponding stage of ancestors. The single-nostriled animals originated during the primordial period out of the skull-less animals by the anterior end of the dorsal marrow developing into the brain, and the anterior end of the sheath of the notochord round about it developing into the skull. The *certain proof* that such single-nostriled and

jawless ancestors of man did exist, is found in the "comparative anatomy of the Myxinoidea."

TWELFTH ANCESTRAL STAGE: **Primæval Fish (Selachii).**

Of all known Vertebrate animals, the ancestral Primæval Fish probably showed most resemblance to the still living Sharks (*Squalacei*). They originated out of the single-nostriled animals by the division of the single nostril into two lateral halves, by the formation of internal genuine gill-arches, a jaw-skeleton, a swimming-bladder, and two pairs of legs (breast-fins or fore legs, and ventral fins or hind legs). The internal organization of these earliest "Jaw-mouths" (*Gnathostoma*) may, upon the whole, have corresponded to the lowest species of Sharks known to us; the swimming-bladder was, however, more strongly developed; in the case of Sharks it exists only as a rudimentary organ. They lived as early as the Silurian period, as is proved by the fossil remains of Sharks (teeth and fin spines) from the Silurian strata. A certain proof that the Silurian ancestors of man and of all the other Gnathostoma were nearest akin to the Selachii, is furnished by the comparative anatomy of the latter.

THIRTEENTH ANCESTRAL STAGE: **Ganoid Fish (Ganoides).**

A portion of the so-called Ganoid fish appear to be closely allied to the Primæval fish. This sub-class of fish, as is well known, was represented in the Palæozoic period by extremely numerous forms in great variety, whereas there now exist only a few remnants of the class. The different groups of the Ganoides vary very much among themselves. Some appear to be of a very ancient type,

closely related to the Selachii (for instance, our present Sturgeon and Sterlet). Others again belong to the highly developed fish (*Lepidosteus, Polypterus*). One group forms a direct transition to the Osseous fish (*Leptolepida*). Another group contains possibly forms belonging to the direct ancestors of Man. These are the remarkable "Fringed fins" (*Crossopterygii*). They are so closely related to the Mud-fish (*Dipneusta*) that many zoologists do not hesitate to class them together. In fact, they appear to form a transition-stage between the Selachii and Dipneusta owing to important advances in the skeleton (both as regards skull as well as fins); hence we may assume with tolerable probability that Ganoids of the Silurian and Devonian periods belonged to the ancestors of Man (Plate XIX., Fig. 21).

Fourteenth Ancestral Stage: **Mud-fish (Dipneusta).**

Our fourteenth ancestral stage is formed by Vertebrate animals, which probably showed a good deal of resemblance to the still living Salamanders (*Ceratodus, Protopterus, Lepidosiren*). They originated out of the Ganoids (probably in the Devonian, towards the beginning of the Primary period) by adaptation to life on land, and by the transformation of the swimming-bladder into an air-breathing lung, and of the nasal cavity (which now opened into the cavity of the mouth) into air-passages. The series of the ancestors of man which breathed air through lungs began at this stage. Their organization may probably in many respects have agreed with that of the still living Ceratodus and Protopterus, but at the same time may have been very different. They probably lived at the beginning

of the Devonian period. Their existence is *proved* by comparative anatomy, which shows the Dipneusta to be an intermediate stage between the Ganoids and Amphibia. The fourteenth ancestral stage might be divided into two: the older Mud-fish (*Monopneumones*) still possessed a simple single lung, like Ceratodus; in the later Dipneusta, however, it had separated into two lungs (*Dipneumones*).

FIFTEENTH ANCESTRAL STAGE: **Gilled Salamanders (Stegocephala).**

Out of those Dipneusta, which we considered the primary forms of all the Vertebrata which breathe through lungs, there developed the class of Amphibia as the main line. Here began the five-toed formation of the foot (the Pentadactyla), which was thence transmitted to the higher Vertebrata, and finally also to Man. The gilled Stegosauria —probably the groups of the Archegosauria and Branchiosauria—must be looked upon as our most ancient ancestors of the class of Amphibia; besides possessing lungs they retained throughout life regular gills, like the still living Proteus and Axolotl. They *originated* out of the Dipneusta by the transformation of the paddling-fins into five-toed legs, and also by the more perfect differentiation of various organs, especially of the vertebral column. In any case they existed about the middle of the Palæolithic, or Primary period, possibly even in the Devonian period; for numerous fossil Stegosauria are found in coal. The proof that similar gilled Amphibians were our direct ancestors, is given by the comparative anatomy and the ontogeny of Amphibia and Amniota.

SIXTEENTH ANCESTRAL STAGE: **Tailed Amphibians (Salamandrina).**

Our amphibious ancestors which retained their gills throughout life, were replaced at a later period by other Amphibia, which, by metamorphosis, lost the gills which they had possessed in early life, but retained the tail, as in the case of the salamanders and newts of the present day (Tritons). They originated out of the gilled Amphibians by accustoming themselves in early life to breathe only through gills, and later in life only through lungs. They probably existed even in the second half of the Primary, namely, during the Permian period, but possibly even during the Coal period. The proof of their existence lies in the fact that tailed Amphibians form a necessary intermediate link between the preceding and succeeding stages.

SEVENTEENTH ANCESTRAL STAGE: **Primæval Reptiles (Protamnia).**

The name Protamnion we have already given to the primary form of the three higher classes of Vertebrate animals, out of which the Proreptilia and the Promammalia developed as two diverging branches. This ancestral stage might, however, as well be termed the Proreptilia, as it belongs to the group of Reptiles. It originated out of unknown tailed Amphibia by the complete loss of the gills, by the formation of the amnion, of the cochlea, and of the round window in the auditory organ, and of the organs of tears. It originated at latest during the last division of the Primary period, in the Permian period, perhaps as early as the Coal period. Of all the known fossil Vertebrates, its nearest relatives are the Permian primary reptiles (Proterosauria); of living animals, the Lizards (Hatteria, etc.). The certain proof that it once existed lies in the

comparative anatomy and the ontogeny of the Amniota; for all Reptiles, Birds, and Mammals, including Man, agree in so many important characteristics that they must, with full assurance, be admitted to be the descendants of a single common primary form, namely, of the Protamnion.

EIGHTEENTH ANCESTRAL STAGE: **Mammal-Reptiles (Theriosauria).**

Between the Proreptilia or Protamnia—as the earliest, common primary group of all Amniota—and the Promammalia—as the common primary group of Mammals—there must be a series of extinct Reptiles which effected the gradual transformation of the Reptile-form into that of the Mammal. This transformation affected mainly the skeleton (skull, vertebral column, shoulder, and pelvic girdles) on the one hand, and the brain and heart on the other. As the earliest Mammals appeared on earth as early as towards the end of the Trias, the above important transformations probably took place during the beginning of that period, or in the preceding Permian period. Of the numerous fossil Reptiles of that epoch, the Theriosauria are those which must, with more or less probability, be looked to as ancestors of the Mammalia. Many of these Mammal-reptiles, especially Pelycosauria and Rhynchocephala, show peculiarities in the structure of their skeletons, which comparative anatomy may point to as important proofs of that transition.

NINETEENTH ANCESTRAL STAGE: **Primary Mammals (Promammalia).**

We now find ourselves more at home with our ancestors. From the nineteenth up to the twenty-fourth stage they all belong to the large and well-known class of Mammals, the

confines of which we ourselves have as yet not transgressed. The common, long since extinct and unknown primary forms of all Mammalia, which we have named Promammalia, were, at all events as regards internal structure, most closely related to the Beaked animals, or Ornithostoma, of all still living animals (*Ornithorhynchus, Echidna,* p. 329). They differed from the latter, however, by the teeth present in their jaws. The formation of the beak in the Beaked animals of the present day must be looked upon as an adaptive characteristic which developed at a later period. The Promammalia arose out of the Theriosauria (probably only at the beginning of the secondary period, namely, in the Trias) by various advances in their internal organization, as also by the transformation of the epidermal scales into hairs, and by the formation of a mammary gland which furnished milk for the nourishment of the young ones. The certain proof that the Promammalia—inasmuch as they are the common primary forms of all Mammals—also belong to our ancestors, lies in the comparative anatomy and the ontogeny of Mammalia and of Man.

TWENTIETH ANCESTRAL STAGE: **Pouched Animals (Marsupialia).**

The three sub-classes of Mammalia—as we have already seen—stand in such a relation to one another that the Marsupials, both as regards their anatomy and their ontogeny and phylogeny, form the direct transition from the Monotrema to Placental animals (p. 332). Consequently, human ancestors must also have existed among Marsupials. They originated out of the Monotrema—which include the primary Mammalia, or Promammalia—by the division of the cloaca into the rectum and the urogenital sinus, by the

formation of a nipple on the mammary gland, and by the partial suppression of the coracoid bones. The oldest Marsupials at all events existed as early as the Jura period (perhaps even in the Trias); during the Chalk period they passed through a series of stages preparing the way for the origin of Placentalia. The certain proof of our derivation from Marsupials—nearly akin to the still living opossum and kangaroo in their essential inner structure—is furnished by the comparative anatomy and ontogeny of Mammalia (see above, p. 332).

Twenty-first Ancestral Stage: **Semi-apes (Prosimiæ).**

The small group of Semi-apes, as we have already seen, is one of the most important and most interesting orders of Mammalia. It probably contains the direct primary forms of Genuine Apes, and thus also of Man. Our Semi-ape ancestors probably possessed only a very faint external resemblance to the still living, short-footed Semi-apes (Brachytarsi), especially the Maki, Indri, and Lori (p. 361). They originated (probably at the beginning of the Cænolithic, or Tertiary period) out of Marsupials of Rat-like appearance by the formation of a placenta, the loss of the marsupium and the marsupial bones, and by the higher development of the commissures of the brain. Perhaps the Semi-apes have developed out of a branch of the Creodonta, which is at present regarded as the earliest primary group of the carnivorous Placentalia. The certain proof that Genuine Apes, and hence also that our own race, are the direct descendants of Semi-apes, is to be found in the comparative anatomy and the ontogeny of Placental animals (see p. 345).

TWENTY-SECOND ANCESTRAL STAGE: **Tailed Apes (Menocerca).**

Of the two classes of Genuine Apes which developed out of the Semi-apes, it is only the narrow-nosed, or Catarhinæ, which are directly related by blood to Man. Our older ancestors from this group probably resembled the still living Nose-apes and Holy-apes (*Semnopithecus*), which possess jaws and narrow noses like Man, but have a long tail, and their bodies densely covered with hair (p. 375). The Cynopitheci, or Tailed Apes with narrow noses (Catarhina Menocerca), originated out of Semi-apes by the transformation of the jaw, and by the claws on their toes becoming changed into nails; this probably took place as early as the older Tertiary period. The certain proof of our derivation from Tailed Catarhini is to be found in the comparative anatomy and the ontogeny of Apes and of Man.

TWENTY-THIRD ANCESTRAL STAGE: **Man-like Apes (Anthropoides).**

Of all still living Apes the large tail-less, narrow-nosed Apes, namely, the Orang and Gibbon in Asia, the Gorilla and Chimpanzee in Africa, are most nearly akin to Man. It is probable that these Man-like Apes, or Anthropoides, originated during the Mid-tertiary period, namely, in the Miocene period. They developed out of the Tailed Catarhinæ of the preceding stage—with which they essentially agree—by the loss of the tail, the partial loss of the hairy covering, and by the excessive development of that portion of the brain just above the facial portion of the skull. There do not exist direct human ancestors among the Anthropoides of the present day, but they certainly existed among the unknown extinct Human Apes of the Miocene period. The certain proof of their former existence is

furnished by the comparative anatomy of Man-like Apes and of Man (see p. 377).

TWENTY-FOURTH ANCESTRAL STAGE: **Ape-like Men (Pithecanthropi).**

Although the preceding ancestral stage is already so nearly akin to genuine Men that we scarcely require to assume an intermediate connecting stage, still we can look upon the speechless Primæval Men (*Alali*) as this intermediate link. These Ape-like men, or Pithecanthropi, very probably existed towards the end of the Tertiary period. They originated out of the Man-like Apes, or Anthropoides, by becoming completely habituated to an upright walk, and by the corresponding stronger differentiation of both pairs of legs. The fore hand of the Anthropoides became the human hand, their hinder hand became a foot for walking. Although these Ape-like Men must, not merely by the external formation of their bodies, but also by their internal mental development, have been much more akin to real Men than the Man-like Apes could have been, yet they did not possess the real and chief characteristic of man, namely, the articulate human language of words, the corresponding development of a higher consciousness, and the formation of ideas. The certain proof that such Primæval Men without the power of speech, or Ape-like Men, must have preceded men possessing speech, is the result arrived at by an inquiring mind from comparative philology (from the "comparative anatomy" of language), and especially from the history of the development of language in every child ("glottal ontogenesis") as well as in every nation ("glottal phylogenesis") (see p. 406).

TWENTY-FIFTH ANCESTRAL STAGE: **Men (Homines).**

Genuine Men *developed* out of the Ape-like Men of the preceding stage by the gradual development of the animal language of sounds into a connected or articulate language of words. The development of this function, of course, went hand in hand with the development of its organs, namely, the higher differentiation of the larynx and the brain. The transition from speechless Ape-like Men to Genuine or Talking Men probably took place at the beginning of the Quaternary period, namely, in the Diluvial period, but possibly even at an earlier date, in the more recent Tertiary. As, according to the unanimous opinion of most eminent philologists, all human languages are not derived from a common primæval language, we may, with great probability, assume a polyphyletic origin of language, and in accordance with this a polyphyletic transition from speechless Ape-like Men to Genuine Talking Men (see below, p. 403).

With regard to the natural main divisions of the animal system which have already been discussed, the preceding twenty-five principal stages of our chain of ancestors can be divided into the following three groups: 1. Primary animal ancestors (1 and 2 one-celled, 3 and 4 many-celled Protozoa). 2. Invertebrate ancestors (5–9). 3. Vertebrate ancestors (10–16 lower vertebrate ancestors, 17–25 higher vertebrate ancestors). Their chronological and more or less probable distribution among the different main periods of the earth's history we again set forth in the following Survey (compare Chapters XV.–XIX. of my "Anthropogeny," 3rd edit., 1877).

The grand discoveries of recent palæontology, especially among the Vertebrates, justify us in hoping that its further advance will very considerably supplement our knowledge of our animal ancestors. And yet probably the greater portion of the ancestral stages mentioned in the above succession will remain. More stages will be added, and more connecting links between the principal stages will be pointed out, the more that the advances of comparative anatomy and of ontogeny afford us a deeper insight into this most important and most interesting part of phylogeny.

ANCESTRAL LINE OF THE HUMAN PEDIGREE.

M N = Boundary between the Invertebrate and the Vertebrate Ancestors.

Geological Periods.	*Five Series of Ancestors.*	*Twenty-five Main Stages of the Animal Ancestors of Man.*		*Nearest Living Relatives of the Ancestors.*
First Period of the Organic History of the Earth. Archozoic or Primordial Period. A. *Laurentian* B. *Cambrian* C. *Silurian*	First Series: Ancestors from the group of the Primæval Animals (*Protozoa*)	1. Monera	*Monera*	1. Protamœba
		2. One-celled	*Protozoa*	2. Amœba
		3. Many-celled	*Morœada*	3. Morula
		4. Hollow spheres	*Blastœada*	4. Volvox Magosphæra
	Second Series: Ancestors from the group of the Invertebrate Metazoa (*Evertebrata*)	5. Animals with primary stomach	*Gastrœada*	5. Hydra, Prophysema
		6. Flat-worms	*Platoda*	6. Rhabdocœla
		7. Cord-worms	*Nemertina*	7. Nemertina
		8. With branchial gut	*Enteropneusta*	8. Balanoglossus
		9. Animals with primary notochord	*Prochordonia*	9. Copelata
M	. . . .	. . . .	. . . .	. . . . . . N
Palæozoa. Silurian Period	Third Series: Ancestors from the group of the Lower Vertebrates (*Ichthyopsida*)	10. Skull-less	*Acrania*	10. Amphioxus
		11. Round-mouthed	*Cyclostoma*	11. Petromyzon
Devonian Period		12. Primary fish	*Selachii*	12. Squali (Sharks)
		13. Ganoid fish	*Ganoides*	13. Sturio (Sturgeons)
		14. Mud-fish	*Dipneusta*	14. Ceratodus
Carbon (Coal)	Fourth Series: Ancestors from the class of the Amphibia and Reptiles	15. Gilled salamanders	*Stegosauria*	15. Proteus
		16. Tailed	*Urodela*	16. Salamandrina
Permian Period		17. Proreptilia	*Protamnia*	17. Lacertalia (Lizards)
		18. Mammal reptiles	*Theriosauria*	18. Hatteria
Mesozoa. Trias Jura Chalk	Fifth Series: Ancestors from the class of Mammals	19. Primary mammals	*Promammalia*	19. Echidna
		20. Marsupials	*Marsupialia*	20. Didelphys (Pouched rats)
Cænozoa. Tertiary Period		21. Semi-apes	*Prosimiæ*	21. Stenops
		22. Tailed apes	*Cynopitheci*	22. Semnopithecus
		23. Man-like apes	*Anthropoides*	23. Gorilla Orang
Anthrop. Quaternary Period		24. Ape-like men	*Alali*	24. Hylobates (Singing apes)
		25. Speaking men	*Homo*	25. Australian Negroes Hottentots

CHAPTER XXVIII.

MIGRATION AND DISTRIBUTION OF MANKIND. HUMAN SPECIES AND HUMAN RACES.

Age of the Human Race.—Causes of its Origin.—The Origin of Human Language.—Language of Sounds and Language of Ideas.—Singing Apes.—Monophyletic or Single, Polyphyletic or Multiple Origin of the Human Race.—Derivation of Man from many Pairs.—Classification of the Human Races.—Skull-measurements.—System of Twelve Species of Men.—Woolly-haired Men, or Ulotrichis.—Bushy-haired (Papuans, Hottentots).—Fleecy-haired (Caffres, Negroes).—Straight-haired Men, or Lissotrichi.—Stiff-haired (Australians, Malays, Mongols, Arctic, and American Tribes).—Curly-haired (Dravidas, Nubians, Mediterranese.) —Number of Population.—Primæval Home of Man (South Asia, or Lemuria).—Nature of Primæval Men.—The Dream of Primæval Man. —Number of Primæval Languages (Monoglottists and Polyglottists).—Divergence and Migration of the Human Race.—Geographical Distribution of the Human Species.

THE rich treasure of knowledge we possess in the comparative anatomy and the history of the development of Vertebrate animals, has enabled us even now to establish the most important outlines of the human pedigree as shown in our last chapters. We must, however, not expect to be able, as yet, to survey satisfactorily in every detail the history or phylogeny of the human species which will henceforth

form the basis of Anthropology, and of all other sciences. The complete development of this most important science—of which we can only lay the first foundation—must remain reserved for the more accurate and extensive investigations of a future time. This applies also to those more special questions of human phylogeny at which before concluding we will take a cursory glance, namely, the question of the time and place of the origin of the human race, and also of the different species and races into which it has differentiated.

In the first place, the period of the earth's history, within which the slow and gradual transmutation of the most man-like apes into the most ape-like men took place, can of course not be determined by years, nor even by centuries. This much can, however, with full assurance be maintained, for reasons given in our last chapters, that Man is derived from Placental animals. Now, as fossil remains of these Placentalia are found only in the tertiary rocks, the human race can at the earliest have developed within the Tertiary period out of perfected man-like apes. What seems most probable is that this most important process in the history of terrestrial creation occurred towards the end of the Tertiary period, that is in the Pliocene, perhaps even in the Miocene period, but possibly also not until the beginning of the Diluvial period. At all events Man, as such, lived in Central Europe as early as the Diluvial period, contemporaneously with many large, long since extinct mammals, especially with the diluvial elephant, or mammoth (*Elephas primigenius*), the woolly-haired rhinoceros (*Rhinoceros tichorrhinus*), the giant deer (*Cervus euryceros*), the cave bear (*Ursus spelæus*), the cave hyæna (*Hyæna spelæa*), the

cave lion (*Felis spelœus*), etc. The results brought to light by recent geology and archæology as to these fossil men and their animal contemporaries of the diluvial period, are of the greatest interest. But as a closer examination of them would occupy too much of my limited space, I must confine myself here to setting forth their great general importance, and refer for particulars to the numerous writings which have recently been published on the Primæval History of Man, more especially to the excellent works of Charles Lyell,[30] John Lubbock,[44] L. Büchner,[43] Paul Topinard,[68] Carus Sterne,[26] etc.

The numerous and interesting discoveries presented to us by these extensive investigations of late years on the primæval history of the human race, place the important fact (long since probable for many other reasons) beyond a doubt, that the human race, as such, has existed for more than twenty thousand years. But it is also probable that more than a hundred thousand years, perhaps many hundred thousands of years, have elapsed since its first appearance; and, in contrast to this, it must seem very absurd that our calendars still represent the "Creation of the World, according to Calvisius," to have taken place 5841 years ago.

Now, whether we reckon the period during which the human race, as such, has existed and diffused itself over the earth, as twenty thousand, a hundred thousand, or many hundred thousands of years, the lapse of time is in any case extremely small in comparison with the inconceivable length of time which was requisite for the gradual development of the long chain of human ancestors. This is evident even from the small thickness of all Diluvial

deposits in comparison with the Tertiary, and of these again in comparison with the preceding deposits. But the infinitely long series of slcwly and gradually developing animal-forms, from the simplest Moneron to the Gastræa, from the Platode to the Amphioxus, from the Cyclostome to the Primæval Fish, from the Ganoid Fish to the Proreptile, from the Theriosaur to the first Mammal, and from the latter again to Man, also require for their historical development a succession of periods probably comprising many thousands of millions of years.

Those processes of development which led to the origin of the most Ape-like Men out of the most Man-like Apes must be looked for in the two adaptational changes which, above all others, contributed to the making of Man, namely, *upright walk* and *articulate speech.* These two *physiological* functions necessarily originated together with two corresponding *morphological* transmutations, with which they stand in the closest correlation, namely, the *differentiation of the two pairs of limbs and the differentiation of the larynx.* The important perfecting of these organs and their functions must have necessarily and powerfully reacted upon the differentiation of the brain and the mental activities dependent upon it, and thus have paved the way for the endless career in which Man has since progressively developed, and in which he has far outstripped his animal ancestors.

The first and earliest of these three great processes in the development of the human organism probably was the higher differentiation and the perfecting of the extremities which was effected by the habit of an upright walk. By the fore feet more and more exclusively adopting and

retaining the function of grasping and handling, and the hinder feet more and more exclusively the function of standing and walking, there was developed that contrast between the hand and foot which is indeed not exclusively characteristic of man, but which is much more strongly developed in him than in any of the apes most like men. This differentiation of the fore and hinder extremities was, however, not merely most advantageous for their own development and perfecting, but it was followed at the same time by a whole series of very important changes in other parts of the body. The whole vertebral column, and more especially the chest, the girdle of the pelvis and shoulders, as also the muscles belonging to them, thereby experienced those changes which distinguish the human body from that of the most man-like apes. These transmutations were probably accomplished long before the origin of articulate speech; and the human race thus existed for long, with an upright walk and the characteristic human form of body connected with it, before the actual development of human language, which would have completed the second and the more important part of human development. We may therefore distinguish a special (24th) stage in the series of our human ancestors, namely, Speechless Man (*Alalus*), or Ape-man (*Pithecanthropus*), whose body was indeed formed exactly like that of Man in all essential characteristics, but who did not as yet possess articulate speech (see p. 369).

The origin of *articulate language,* and the *higher differentiation and perfecting of the larynx* connected with it, must be looked upon as a later, and the most important stage in the process of the development of Man.

It was, doubtless, this process which above all others helped to create the deep chasm between man and animals, and which also first caused the most important progress in the mental activity and the perfecting of the brain connected with it. There indeed exists in very many animals a language for communicating sensations, desires, and thoughts, partly a language of gestures, partly a language of feeling or touch, partly a language of cries or sounds; but a real language of words or ideas, a so-called "articulate" language, which by abstraction changes sounds into words, and words into sentences, belongs, as far as we know, exclusively to Man. The song of birds only, is a somewhat similar physiological accomplishment.

The language of mammals, as, for instance, the barking of dogs, the nocturnal cries of cats "fit to melt a heart of stone," the neighing of horses, the trumpeting of elephants, etc., are merely a language of interjection, *i.e.* disjointed cries which communicate certain feelings or wishes of the mammal. Among mammals that live in communities, these cries may have a further significance, as regards their power of sensation or will, and may express commands, warnings, or appeals for help, etc. The effect of these cries may, moreover, be essentially enhanced by the language of gesture. Yet, although most of these languages of interjection or cries stand far below the "inarticulate" language of ideas or words, we must nevertheless regard the former as the phylogenetic, preliminary stage towards the latter, in the same way as the notes of singing birds may be said to be the first step towards the language of tones or music. This assumption is corroborated by the remarkable fact that, apart from Man, there is a second species of singing

mammal, and that this mammal belongs to the family of Man-like Apes. An Indian Gibbon (Hylobates agilis) sings in perfectly pure and melodious notes up and down the scale of an octave, the distance between the notes being exactly half a note. These Indian "singing apes" stand about as far above the American "howling apes" as the nightingale stands above the crow.

The origin of human language must, more than anything else, have had an ennobling and transforming influence upon the mental life of Man, and consequently upon his brain. The higher differentiation and perfecting of the brain and mental life as its highest function, developed in direct correlation with its expression by means of speech. Hence, the highest authorities in comparative philology justly see in the development of human speech the most important process which distinguishes Man from his animal ancestors. This has been especially set forth by August Schleicher, in his treatise "On the Importance of Speech for the Natural History of Man."[6] In this relation we see a connection of the closest kind between comparative zoology and comparative philology; and here the theory of development assigns to the latter the task of following the origin of language step by step. This task, as interesting as it is important, has of late years been successfully undertaken by many inquirers, but more especially by Lazarus Geiger and Wilhelm Bleek, who has been occupied for many years in South Africa with the study of the languages of the lowest races of men, and hence has been enabled to solve the question. August Schleicher more especially discusses, in accordance with the theory of selection, how the various forms of speech, like all other organic forms and functions,

have developed by the process of natural selection, and have divided into many species and dialects.

I have no space here to follow the process of the formation of language, and must refer in regard to this to the above-mentioned important work of Wilhelm Bleek, "On the Origin of Language."[35] This distinguished philologist, in a letter addressed to me, expressed it as his opinion that *all the various human languages were of a uniform or monistic origin.* "They all possess genuine pronomina and the division of the parts of speech dependent on these. And the history of the development of language shows us clearly how the possession of genuine pronomina was acquired by adaptation, and this in a manner which could not possibly have occurred more than once." However, many other eminent philologists are of the opinion that human language was probably of a multiple or polyphyletic origin. At least Schleicher, one of the first authorities on the subject, maintains that "even the beginnings of language—in sounds as well as in regard to ideas and views which were reflected in sounds, and further, in regard to their capability of development—must have been different. For it is positively impossible to trace all languages to one and the same primæval language. An impartial investigation rather shows that there are as many primæval languages as there are races."[6] In like manner, Friedrich Müller[42] and other eminent linguists assume a free and independent origin of the families of languages and their primæval stocks. It is well known, however, that the boundaries of these tribes of languages and their ramifications are by no means always the boundaries of the different human species, or the so-called "races," distinguished by us on account of

their bodily characteristics. This, as well as the complicated relations of the mixture of races, and the various forms of hybrids, is the great difficulty lying in the way of tracing the human pedigree in its individual branches, species, races, varieties, etc.

In spite of these great and serious difficulties, we cannot here refrain from taking one more cursory glance at the ramification of the human pedigree, and at the same time considering the much-discussed question of the monophyletic or polyphyletic origin of the human race, and its species or races, from the point of view of the theory of descent. As is well known, two great parties have for a long time been at war with each other upon this question. The *monophylists* (or monogenists) maintain the unity of origin and the blood-relationship of all races of men. The *polyphylists* (or polygenists), on the other hand, are of opinion that the different races of men are of independent origin. According to our previous genealogical investigations we cannot doubt that, at least in a *wide sense,* the monophyletic opinion is the right one. For even supposing that the transmutation of Man-like Apes into Men had taken place several times, yet those Apes themselves would again be allied by the one pedigree common to the whole order of Apes, at all events to the Catarhini. The question, therefore, would always be merely about a nearer or remoter degree of blood-relationship. In a narrower sense, on the other hand, the polyphylist's opinion would probably be right, inasmuch as the different primæval languages have developed quite independently of one another. Hence, if the origin of an articulate language is considered as the real and principal act of humanification, and the species of

the human race are distinguished according to the roots of their language, it might be said that the different races of men had originated, independently of one another, from different branches of primæval, speechless men directly sprung from apes, who each formed their own primæval language. Still they would, of course, be connected further up or lower down at their root, and finally be derived from a common primæval stock.

While we hold the latter of these convictions, and while we for many reasons believe that the different species of speechless primæval men were all derived from a common ape-like human form, we do not, of course, mean to say that *all men are descended from one pair*. This latter supposition, which our modern Indo-Germanic culture has taken from the Semitic myth of the Mosaic history of creation, is by no means tenable. The whole of the celebrated dispute, as to whether the human race is descended from a single pair or not, rests upon a completely false way of putting the question. It is just as senseless as the dispute as to whether all sporting dogs or all race-horses are descended from a single pair. We might with equal justice ask whether all Germans or all Englishmen are "descended from a single pair," etc. A "first human pair," or "a first man," has in fact never existed, any more than there ever existed a first pair or a first individual of Englishmen, Germans, race-horses, or sporting dogs. The origin of a new species, of course, always results from an existing species, by a long chain of many different individuals sharing the slow process of transformation. Supposing that we had all the different pairs of Human Apes and Ape-like Men before us—which belong to the true

ancestors of the human race—it would even then be quite impossible (without doing so most arbitrarily) to call any one of these pairs of ape-like men "the first pair." As little can we derive each of the twelve races or species of men, which we shall consider directly, from a "first pair."

The difficulties met with in classifying the different races or species of men are quite the same as those which we discover in classifying animal and vegetable species. In both cases forms apparently quite different are connected with one another by a chain of intermediate forms of transition. In both cases the dispute as to what is a kind or a species, what a race or a variety, can never be determined. Since Blumenbach's time, as is well known, it has been thought that mankind may be divided into five races or varieties, namely: (1) the Ethiopian, or black race (African negro); (2) the Malayan, or brown race (Malays, Polynesians, and Australians); (3) the Mongolian, or yellow race (the principal inhabitants of Asia and the Esquimaux of North America); (4) the American, or red race (the aborigines of America); and (5) the Caucasian, or white race (Europeans, north Africans, and south-western Asiatics). All of these five races of men, according to the Jewish legend of creation, are said to have been descended from "a single pair"—Adam and Eve,—and in accordance with this are said to be varieties of one kind or species. If, however, we compare them without prejudice, there can be no doubt that the differences of these five races are as great and even greater than the "specific differences" by which zoologists and botanists distinguish recognized "good" animal and vegetable species ("bonæ species"). The excellent palæontologist Quenstedt is right in maintaining that, "if Negroes

and Caucasians were snails, zoologists would universally agree that they represented two very distinct species, which could never have originated from one pair by gradual divergence."

The characteristics by which the races of men are generally distinguished are partly taken from the formation of the hair, partly from the colour of the skin, and partly from the formation of the skull. In regard to the last character, two extremes are distinguished, namely, long heads and short heads. In long-headed men (*Dolichocephali*), whose strongest development is found in Negroes and Australians, the skull is long, narrow, and compressed on the right and left. In short-headed men (*Brachycephali*), on the other hand, the skull is compressed in an exactly opposite manner, from the front to the back, is short and broad, which is especially striking in the case of the Mongolians. Medium-headed men (*Mesocephali*), standing between the two extremes, predominate especially among Americans. In every one of these three groups we find men with slanting teeth (*Prognathi*), whose jaws, like those of the animal snout, strongly project, and whose front teeth therefore slope in front; and men with straight teeth (*Orthognathi*), whose jaws project but little, and whose front teeth stand perpendicularly. During the last thirty years a great deal of time and trouble has been devoted to the careful examination and measurement of the forms of skulls, which has, however, not been rewarded by corresponding results. For within a single species, as for example within the Mediterranean species, the form of the skull may vary so much that both extremes are met with in the same species. Besides, the useless work of this

so-called "exact craniometry" was performed for the most part by anthropologists, who did not possess the indispensable preliminary knowledge of the comparative anatomy of the Vertebrate skull. Much better starting-points for the classification of the human species are furnished by the nature of the hair and speech, because they are much more strictly hereditary than the form of the skull.

Comparative philology seems especially to be becoming an authority as regards the complicated question as to the blood-relationship between the larger and smaller groups of "races." In the latest great work on the races of men, which Friedrich Müller has published in his excellent "Ethnography,"[42] he therefore justly places language in the foreground. Next to it the nature of the hair of the head is of great importance; for although it is in itself of course only a subordinate morphological character, yet it seems to be strictly transmitted within the race. Of the twelve species of men distinguished on the following table (p. 416), the four lower species are characterized by the woolly nature of the hair of their heads; every hair is flattened like a tape, and thus its section is oval. These four species of woolly-haired men (*Ulotrichi*) we may reduce into two groups—tuft-haired and fleecy-haired. The hair on the head of tuft-haired men (*Lophocomi*), Papuans and Hottentots, grows in unequally divided small tufts. The woolly hair of fleecy-haired men (*Eriocomi*), on the other hand, in Caffres and Negroes, grows equally all over the skin of the head. All Ulotrichi, or woolly-haired men, have slanting teeth and long heads, and the colour of their skin, hair, and eyes is always very dark. All are inhabitants of the Southern Hemisphere; it is only in Africa that they

come north of the equator. They are on the whole at a much lower stage of development, and more like apes, than most of the Lissotrichi, or straight-haired men. The Ulotrichi are incapable of a true inner culture and of a higher mental development, even under the favourable conditions of adaptation now offered to them in the United States of North America. No woolly-haired nation has ever had an important "history."

In the eight higher races of men, which we comprise as straight-haired (*Lissotrichi*), the hair of the head is never actually woolly, although it is very much frizzled in some individuals. Every separate hair is cylindrical (not like a tape), and hence its section is circular (not oval).

The eight races of Lissotrichi may likewise be divided into two groups—stiff-haired and curly-haired. Stiff-haired men (*Euthycomi*), the hair of whose heads is quite smooth and straight, and not frizzled, include Malays, Mongolians, Arctic tribes, and Americans. Curly-haired men (*Euplocami*), on the other hand, the hair of whose heads is more or less curly, and in whom the beard is more developed than in all other species, include the Australians, Dravidas, Nubians, and Mediterranean races (compare Plate XX.).

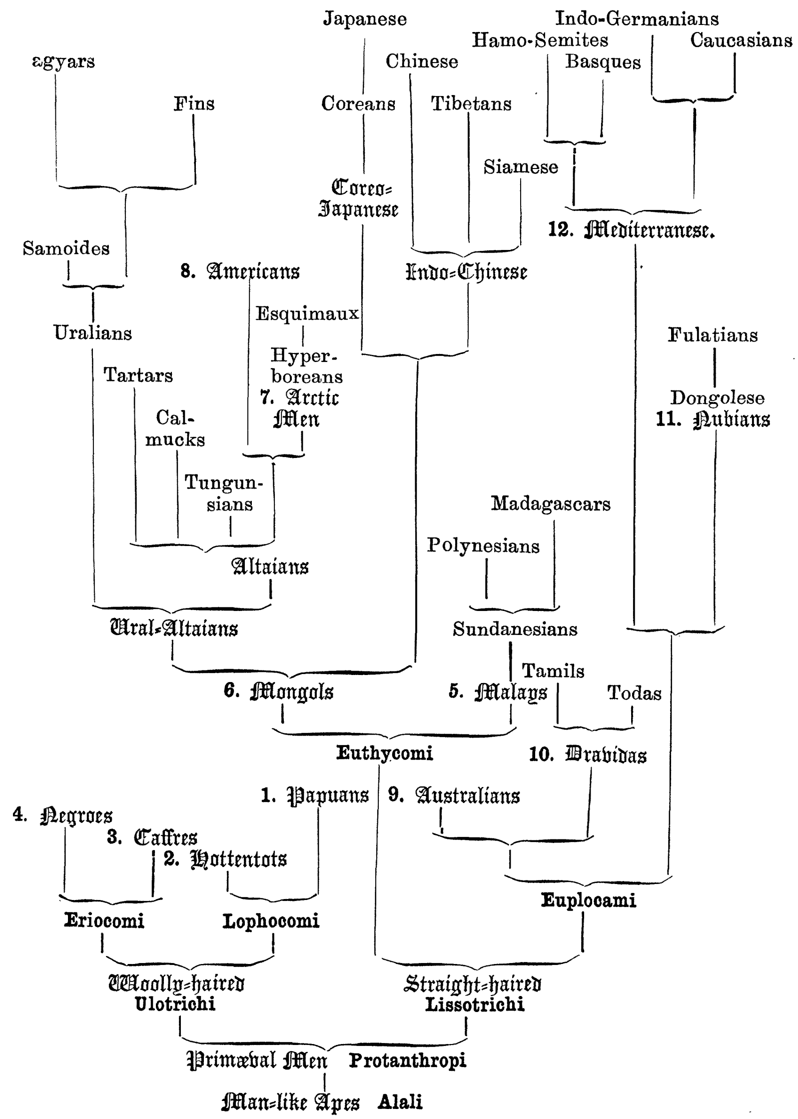
Now, before we venture upon the attempt hypothetically to explain the phyletic history of mankind, and the genealogical connection of its different species, we will premise a short description of the twelve named species and of their distribution. In order clearly to survey their geographical distribution, we must go back some three or four centuries, to the time when the East Indian Islands and America were first discovered, and when the present great mingling of species, and more especially the influx of the

SYSTEMATIC SURVEY

Of the 12 *Species of Men and their* 36 *Races.*

(Compare Plate XX.)

	Species.	*Races.*	*Home.*	*Immigrated from the*
1, 2. *Lophocomi.*	1. Papuan **Homo Papua**	1. Nigritos	Malacca, Philippine Islands	West
		2. New Guinea men	New Guinea	West
		3. Melanesians	Melanesia	North-west
		4. Tasmanians	Van Diemen's Land	North-east
	2. Hottentot **Homo Hottentottus**	5. Hottentots	The Cape	North-east
		6. Bushmen	The Cape	North-east
3, 4. *Eriocomi.*	3. Kaffre **Homo Cafer**	7. Zulu Kaffres	Eastern South Africa	North
		8. Bechuanas	Central South Africa	North-east
		9. Congo Kaffres	Western South Africa	East
	4. Negro **Homo Niger**	10. Tibu negroes	Tibu district	South-east
		11. Soudan negroes	Soudan	East
		12. Senegambians	Senegambia	East
		13. Nigritians	Nigritia	East
5–8. *Euthycomi.*	5. Malay **Homo Malayus**	14. Sundanesians	Sunda Archipelago	West
		15. Polynesians	Pacific Archipelago	West
		16. Natives of Madagascar	Madagascar	East
	6. Mongolian **Homo Mongolus**	17. Indo-Chinese	Tibet, China	South
		18. Coreo-Japanese	Corea, Japan	South-west
		19. Altaians	Central Asia, North Asia	South
		20. Uralians	North-western Asia, Northern Europe, Hungary	South-east
	7. Arctic Men **Homo Arcticus**	21. Hyperboreans	Extreme N.E. of Asia	South-west
		22. Esquimos	The extreme north of America	West
	8. American **Homo Americanus**	23. North Americans	North America	North-west
		24. Central Americans	Central America	North
		25. South Americans	South America	North
		26. Patagonians	The extreme south of South America	North
9–12. *Euplocomi.*	9. Australian **Homo Australis**	27. North Australians	North Australia	North
		28. South Australians	South Australia	North
	10. Dravidas **H. Dravida**	29. Tamils	Further India	North
		30. Todas	Nilgherri	North
	11. Nubian **Homo Nuba**	31. Dongolese	Nubia	East
		32. Fulatians	Fulu-land (Central Africa)	East
	12. Mediterranese **Homo Mediterraneus**	33. Caucasians	Caucasus	South-east
		34. Basque	Extreme north of Spain	South ?
		35. Hamo-Semites	Arabia, North Africa, etc.	East
		36. Indo-Germanic tribes	South-western Asia, Europe, etc.	South-east


Japanese
Indo-Germanians
Hamo-Semites
Caucasians
agyars
Chinese
Basques
Fins
Coreans
Tibetans
Siamese
Coreo-Japanese
12. Mediterranese.
Samoides
8. Americans
Indo-Chinese
Esquimaux
Uralians
Fulatians
Hyper-boreans
Tartars
7. Arctic Men
Dongolese
Cal-mucks
11. Nubians
Tungun-sians
Madagascars
Polynesians
Altaians
Ural-Altaians
Sundanesians
Tamils
6. Mongols
5. Malays
Todas
Euthycomi
10. Dravidas
1. Papuans
9. Australians
4. Negroes
3. Caffres
2. Hottentots
Euplocami
Eriocomi
Lophocomi
Woolly-haired
Ulotrichi
Straight-haired
Lissotrichi
Primæval Men
Protanthropi
Man-like Apes
Alali

Indo-Germanic race, had as yet not made great progress. We begin with the lowest stages, with the woolly-haired men (Ulotrichi), all of whom are prognathic Dolichocephali.

The Papuan (*Homo Papua*), of all the still living human species, is perhaps most closely related to the original primary form of woolly-haired men. This species now inhabits only the large island of New Guinea and the Archipelago of Melanesia lying to the east of it (Solomon's Islands, New Caledonia, the New Hebrides, etc.). But scattered remnants of it are also still found in the interior of the peninsula of Malacca, and likewise in many other islands of the large Pacific Archipelago; mostly in the inaccessible mountainous parts of the interior, and especially in the Philippine Islands. The but lately extinct Tasmanians or natives of Van Diemen's Land belonged to this group. From these and other circumstances it is clear that the Papuans in former times possessed a much larger area of distribution in south-eastern Asia. They were driven out by the Malays and forced eastwards. The skin of all Papuans is of a black colour, sometimes more inclining to brown, sometimes more to greyish blue. Their woolly hair grows in tufts, is spirally twisted in screws, and often more than a foot in length, so that it forms a strong woolly wig, which stands far out from the head. Their face, below the narrow depressed forehead, has a large turned-up nose and thick protruding lips. The peculiar form of their hair and speech so essentially distinguishes the Papuans from their straight-haired neighbours, from the Malays as well as from the Australians, that for this reason, as well as others, they must be regarded as an entirely distinct species.

Closely related to the Papuans by the tufted growth of hair, but geographically widely separated from them, are the Hottentots (*Homo Hottentottus*). They inhabit exclusively the southernmost part of Africa, the Cape and the adjacent parts, and have immigrated there from the north-east. The Hottentots, like their original kinsmen the Papuans, occupied in former times a much larger area (probably the whole of Eastern Africa), and are now approaching their extinction. Besides the genuine Hottentots—of whom there now exist only the two tribes of the Coraca (in the eastern Cape districts) and the Namaca (in the western portion of the Cape)—this species also includes the Bushmen (in the mountainous interior of the Cape). The woolly hair of all Hottentots grows in tufts, like brushes, as in the case of Papuans. Both species also agree in the posterior part of the body, being in the female sex specially inclined to form a great accumulation of fat (Steatopygia). But the skin of Hottentots is much lighter, of a yellowish brown colour. Their very flat face is remarkable for its small fore-head and nose, and large nostrils. The mouth is very broad, with big lips, the chin small and pointed. Their speech is characterized by several quite peculiar guttural sounds.

The next neighbours and kinsmen of Hottentots are Kaffres (*Homo Cafer*). This woolly-haired human species is, however, distinguished, like the following one (the genuine Negro), from Hottentots and Papuans by the woolly hair not being divided into tufts, but covering the head as a thick fleece. The colour of their skin varies through all shades, from the yellowish black of the Hottentot to the brown black or pure black of the genuine Negro. While in former times the race of Kaffres was assigned to a very

small area of distribution, and was generally looked upon only as a variety of the genuine Negro, this species is now considered to include almost the whole of the inhabitants of equatorial Africa, from the 20th degree south latitude to the 4th degree north; consequently, all South Africans, with the exception of the Hottentots. They include especially the inhabitants of the Zulu, Zambesi, and Mozambique districts on the east coast, the large human families of the Beschuans or Setschuans in the interior, and the Herrero and Congo tribes of the west coast. They too, like the Hottentots, have immigrated from the north-east. Kaffres, who were usually classed with Sudan Negroes, differ very essentially from them by the formation of their skull and by their speech. Their face is long and narrow, their forehead high, and their nose prominent and frequently curved, their lips not so protruding, and their chin pointed. The many languages of the different tribes of Kaffres can all be derived from an extinct primæval language, namely, from the Bantu language.

The group of the Sondians, or the genuine Negro (*Homo Niger*) in the narrow sense—when Kaffres, Hottentots, and Nubians are separated from him—now only include the Tibus, in the eastern parts of the Sahara, the Sudan people, or Sudians, who inhabit the south of that large desert, and the inhabitants of the Western Coast of Africa, from the mouth of the Senegal in the north, to beyond the estuary of the Niger in the south (Senegambians and Nigerians). Genuine Negroes are accordingly confined between the equator and the tropic of Capricorn, and only a small portion of the Tibu tribe in the east have gone beyond this boundary. The Negro species has spread within this zone,

coming from the east. The colour of the skin of genuine Negroes is always more or less of a pure black. Their skin is velvety to the touch, and characterized by a peculiar offensive exhalation. Although Negroes agree with Kaffres in the formation of the woolly hair of the head, yet they differ essentially in the formation of their face. Their forehead is flatter and lower, their nose broad and thick, not prominent, their lips large and protruding, and their chin very short. Genuine Negroes are moreover distinguished by very thin calves and very long arms. This species of men must have branched into many separate tribes at a very early period, for their numerous and entirely distinct languages can in no way be traced to one primæval language.

To the four woolly-haired species of men just discussed, straight-haired men (*Homines Lissotrichi*) stand in strong contrast, as another main branch of the genus. Four of the eight species of the latter, as we have seen, can be comprised as stiff-haired (*Euthycomi*) and four as curly-haired (*Euplocami*). We shall in the first place consider the former, which include the primæval inhabitants of the greater part of Asia and the whole of America.

The Malay (*Homo Malayus*), the brown race of ethnographers, although not a large species, is important in regard to its genealogy. An extinct south Asiatic human species, very closely related to the Malays of the present day, must probably be looked upon as the common primary form of this and the following higher human species. We will call this hypothetical primary species, Primæval Malays, or Promalays. The Malays of the present day are divided into two widely dispersed races, the *Sundanesians*, who inhabit Malacca, the Sunda Islands (Sumatra, Java, Borneo,

etc.) and the Philippine Islands, and the *Polynesians*, who are dispersed over the greater portion of the Pacific Archipelago. The northern boundary of their wide tract of distribution is formed on the east by the Sandwich Islands (Hawai), and on the west by the Marian Islands (Ladrones); the southern boundary on the east is formed by the Mangareva Archipelago, and on the west by New Zealand. The inhabitants of Madagascar are an especial branch of Sundanesians who have been driven to the far west. This wide pelagic distribution of the Malays is explained by their partiality for nautical life. Their primæval home is the south-eastern portion of the Asiatic continent, from whence they spread to the east and south, and drove the Papuans before them. The Malays, in the formation of body, are nearest akin to the Mongols, but are also nearly allied to the curly-haired Mediterranese. They are generally short-headed, more rarely medium-headed, and very rarely long-headed. Their hair is black and stiff, but frequently somewhat curled. The colour of their skin is brown, sometimes yellowish, or of a cinnamon colour, sometimes reddish or copper brown, more rarely dark brown. In regard to the formation of face, Malays in a great measure form an intermediate stage between the Mongols and the Mediterranese; they can frequently not be distinguished from the latter. Their face is generally broad, with prominent nose and thick lips, the opening for their eyes not so narrowly cut and slanting as in Mongols. The near relationship between all Malays and Polynesians is proved by their language, which indeed broke up at an early period into many small branches, but still can always be traced to a common and quite peculiar primæval language.

The Mongol (*Homo Mongolus*) is, next to the Mediterranese, the richest in individuals. Among them are all the inhabitants of the Asiatic continent, excepting the Hyperboreans in the north, the few Malays in the south-east (Malacca), the Dravidas in Western India, and the Mediterranese in the south-west. In Europe this species of men is represented by the Fins and Lapps in the north, and also by a portion of the Turks. The colour of the Mongol is always distinguished by a yellow tone, sometimes a light pea green, or even white, sometimes a darker brownish yellow. Their hair is always stiff and black. The form of their skull is, in the great majority of cases, decidedly short (especially in Kalmucks, Baschkirs, etc.), but frequently of medium length (Tartars, Chinese, etc.). Among them we never meet with genuine long-headed men. The narrow openings of their eyes, which are generally slanting, their prominent cheek-bones, broad noses, and thick lips are very striking, as well as the round form of their faces. The language of the Mongols is probably traceable to a common primæval language; but the monosyllabic languages of the Indo-Chinese races, and the polysyllabic languages of the other Mongol races, stand in contrast as two main branches which separated at an early time. The monosyllabic tribes of the Indo-Chinese include the Tibetans, Birmans, Siamese, and Chinese. The polysyllabic Mongols are divided into three races, namely: (1) the Coreo-Japanese (Coreans and Japanese); (2) the Altaians (Tartars, Turks, Kirgises, Kalmucks, Buriats, Tungusians); and (3) the Uralians (Samoiedes, Fins). The Magyars of Hungary are descended from the Fins.

The Polar men (*Homo Arcticus*) must be looked upon as

a branch of the Mongolian human species. We comprise under this name the inhabitants of the Arctic Polar lands of both hemispheres, the Esquimaux (and Greenlanders) in North America, and the Hyperboreans in North-eastern Asia (Jukagirs, Tschuksches, Kuriaks, and Kamtschads). By adaptation to the Polar climate, this human race has become so peculiarly transformed that it may be considered as a distinct species. Their stature is low and of a square build; the formation of their skull of medium size or even long; their eyes narrow and slanting like the Mongols; their cheek-bones prominent, and their mouth wide. Their hair is stiff and black; the colour of their skin is of a light or dark brown tinge, sometimes more inclined to white or to yellow, like that of the Mongols, sometimes more to red, like that of the Americans. The languages of Polar men are as yet little known, but they differ both from the Mongolian and from the American. Polar men must probably be regarded as a remnant and a peculiarly adapted branch of that tribe of Mongols which emigrated from North-eastern Asia to North America, and populated that part of the earth.

At the time of the discovery of America, that part of the earth was peopled (setting aside the Esquimaux) only by a single human species, namely, by the Redskins, or American Indians (*Homo Americanus*). Of all other human species they are most closely related to the two preceding. The form of their skull is generally a medium one, rarely short or long-headed. Their forehead broad and very low; their nose large, prominent, and frequently aquiline; their cheek-bones prominent; their lips rather thin than thick. The colour of their skin is characterized by a red fundamental

tint, which is, however, sometimes pure copper-red, or light red, sometimes a deeper reddish brown, yellow brown, or olive brown. The numerous languages of the various American races and tribes are extremely different, yet they agree in their original foundation. Probably America was first peopled from north-eastern Asia by the same tribe of Mongols from whom the Polar men (Hyperboreans and Esquimaux) have also branched. This tribe first spread in North America, and from thence migrated over the isthmus of Central America down to South America, at the extreme south of which the species degenerated very much by adaptation to the very unfavourable conditions of existence. But it is also possible that Mongols and Polynesians immigrated from the west and mixed with the former tribe. In any case the aborigines of America came over from the Old World, and did not, as some suppose, in any way originate out of American apes. Catarhini, or Narrow-nosed Apes, never at any period existed in America.

The four human species still to be considered—the Australians, Dravidas, Nubians, and Mediterranese—agree in several characteristics which seem to establish a close relationship between them, and distinguish them from the preceding species. The chief of these characteristics is the strong development of the beard, which in all other species is either entirely wanting or but very scanty. The hair of their heads is generally not so lank and smooth as in the four preceding species, but in most cases more or less curly. Other characteristics also seem to favour our classing them in one main group of curly-haired men (Euplocami). Out of the common primary form of the Euplocami—whose original home we look for in Southern Asia—there probably

arose two diverging branches, one of which turned towards the south-east, the other towards the north-west. The Australians and Dravidas are remnants of the former, whereas the Nubians and Mediterranese are descended from the latter.

The lowest stage of all straight-haired men, and perhaps of all the still living human species, is occupied by the Australian or Austral Negro (*Homo Australis*). This species seems to be exclusively confined to the large island of Australia; it resembles the genuine African Negro by its black or black-brown skin, with an offensive smell, by its very slanting teeth and long-headed form of skull, the receding forehead, broad nose, protruding lips, and also by the almost entire absence of calves. On the other hand, the Australians differ from genuine Negroes as well as from their nearest neighbours, the Papuans, by the much weaker and more delicate structure of their bones, and more especially by the formation of the hair of their heads, which is not woolly or frizzled, but either quite lank or only slightly curled. The very low stage of bodily and mental development of the Australian is, perhaps, not altogether original, but has arisen by degeneration, that is, by adaptation to the very unfavourable conditions of existence in Australia. They probably immigrated to their present home from the north or north-west, as a very early offshoot of the Euthycomi. They are probably more closely related to the Dravidas, and hence to the Euplocami, than the other Euthycomi. The very peculiar language of the Australians is broken up into numerous small branches, which are grouped into a northern and a southern class.

The Dravida man (*Homo Dravida*) seems to be directly

allied to the Austral Negro. At present this primæval species is only represented by the Deccan tribes in the southern part of Hindostan, and by the neighbouring inhabitants of the mountains on the north-east of Ceylon. But in earlier times this race seems to have occupied the whole of Hindostan, and to have spread even further. It shows, on the one hand, traits of relationship to the Australians and Malays; on the other, to the Mongols and Mediterranese. Their skin is either of a light or dark brown colour; in some tribes, of a yellowish brown, in others, almost black brown. The hair of their heads, as in Mediterranese, is more or less curled, neither quite smooth, like that of the Euthycomi, nor actually woolly, like that of the Ulotrichi. The strong development of the beard is also like that of the Mediterranese. The oval form of face seems partly to be akin to that of the Malays, partly to that of the Mediterranese. Their forehead is generally high, their nose prominent and narrow, their lips slightly protruding. During my sojourn in Ceylon (during the winter of 1881–2) I had the opportunity of seeing a great many Dravidas of the tribe of the Tamils, especially in the plantations on the higher parts of the island. I was surprised at the marked type of this independent black-brown race of men, which is as far removed in formation of face and structure of body from the cinnamon-coloured Singalese (Arians), as from the woolly-haired Negroes, with whom they have no connection whatever. A very remarkable tribe of the Dravidas (perhaps an independent race) is formed by the Todas in the Nilgherry Hills; the upper part of their black body is thickly clothed with hair (as in the Ainos in Japan), and the arches of their eyebrows protrude far in

front of their flat foreheads, as in the skull from the Neander-thal. Perhaps the Todas and the other Dravida inhabitants of the mountainous parts of further India are a remnant of a primæval race of men, which were closely allied to Primitive Men. Their language is now very much mixed with Indo-Germanic elements, but seems to have been originally derived from a very peculiar primæval language.

The Nubian (*Homo Nuba*) has caused ethnographers no fewer difficulties than the Dravida species. By this name we understand not merely the real Nubians (Schangallas, or Dongolese), but also their near kinsmen, the Fulas, or Fellaheen. The real Nubians inhabit the countries of the Upper Nile (Dongola, Schangalla, Barabra, Cordofan); the Fulas, or Fellatas, on the other hand, have thence migrated far westward, and now inhabit a broad tract in the south of the western Sahara, hemmed in between the Soudanians in the north and the Nigerians in the south. The Nubian and Fula races are generally either classed with Negroes or with the Hamitic races (thus with Mediterranese), but are so essentially different from both that they must be regarded as a distinct species. In former times they very probably occupied a large part of North-eastern Africa. The skin of the Nubian and Fula races is of a yellowish or reddish brown colour, more rarely dark brown or approaching to black. Their hair is not woolly but curled, frequently even quite smooth; its colour is dark brown or black. Their beard is much more strongly developed than in Negroes. The oval and often noble formation of their faces approaches more to the Mediterranean than to the Negro type. Their forehead is high and broad, their nose

prominent and not flat, their lips not so protruding as in the Negro. Perhaps the ancient Egyptians belonged to this race. The languages of the Nubian races seem to possess no relationship to those of genuine Negroes.

The Caucasian, or Mediterranean man (*Homo Mediterraneus*), has from time immemorial been placed at the head of all races of men, as the most highly developed and perfect. It is generally called the Caucasian race, but as, among all the varieties of the species, the Caucasian branch is the least important, we prefer the much more suitable appellation proposed by Friedrich Müller, namely, that of Mediterranese. For the most important varieties of this species, which are moreover the most eminent actors in what is called "Universal History," first rose to a flourishing condition on the shores of the Mediterranean. The former area of the distribution of this species is expressed by the name "Indo-Atlantic," whereas at present it is spread over the whole earth, and is overcoming most of the other species in the struggle for existence. In bodily as well as in mental qualities, no other human species can equal the Mediterranean. This species alone (with the exception of the Mongolian) has had an actual history; it alone has attained to that degree of civilization which seems to raise man above the rest of nature.

The characteristics which distinguish the Mediterranese from the other species of the race are well known. The chief of the external features is the light colour of the skin, which however exhibits all shades, from pure white or reddish white, through yellow or yellowish brown to olive brown or even dark brown. The growth of the hair is generally strong, the hair of the head more or less curly,

the hair of the beard stronger than in any of the other species. The form of the skull shows a great development in breadth; medium heads predominate upon the whole, but long and short heads are also widely distributed. It is only in this one species of men that the body as a whole attains that symmetry in all parts, and that equal development, which we call the type of perfect human beauty. The languages of all the races of this species can by no means be traced to a single common primæval language; we must at least assume four radically different primæval languages. In accordance with this we must also assume within this one species four different races, which are only connected at their root. Two of these races, the Basques and Caucasians, now exist only as small remnants. The Basques, which in earlier times peopled the whole of Spain and the south of France, now inhabit but a narrow tract of land on the northern coast of Spain, on the Bay of Biscay. The remnant of the Caucasian race (the Daghestans, Circassians, Mingrelians, and Georgians) are now confined to the districts of Mount Caucasus. The language of the Caucasians as well as that of the Basques is entirely peculiar, and can be traced neither to the Semitic nor to the Indo-Germanic primæval languages.

Even the languages of the two principal races of the Mediterranean species—the Semitic and Indo-Germanic—cannot be traced to a common origin, and consequently these two races must have separated at a very early period. Hamo-Semites and Indo-Germani are, at most, only connected far down at the root. The Hamo-Semitic race likewise separated at a very early period into two diverging branches, namely, into the Hamitic branch (in

Egypt) and the Semitic branch (in Arabia). The Egyptian or African branch, the Hamites, embraces the ancient inhabitants of Egypt, the large group of the Lybians and Berbers, who occupy the whole of Northern Africa, and in earlier times also peopled the Canary Islands, and, finally, also the group of the Ethiopians, the Bedsha, Galla, Danakil, Somali, and other tribes which occupy all the north-eastern shores of Africa as far as the equator. The Arabic or Asiatic branch, comprising the Semites, divides into two main branches: Arabians (South Semites) and Primary Jews (North Semites) The Arabic main branch comprises the inhabitants of the great Arabian peninsula, the very ancient family of genuine Arabs (the "primary type of the Semites"), the Abyssinians, and Moors, the extinct Mesopotamians (Assyrians, Babylonians, and Early Phœnicians), the Aramæans (Syrians, Chaldæans, Samaritans), and then the very highly developed Semitic groups, the inhabitants of Palestine—the Phœnicians and the actual Jews or Hebrews.

Lastly, the Indo-Germanic race, which has far surpassed all the other races of men in mental development, separated at a very early period, like the Semitic, into two diverging branches, the Ario-Romaic and the Slavo-Germanic branches. Out of the former arose on the one hand the Arians (Indians and Iranians), on the other the Græco-Roman (Greeks and Albanians, Italians and Kelts). Out of the Slavo-Germanic branch were developed on the one hand the Slavonians (Russian, Bulgarian, Tchec, and Baltic tribes), on the other the Germani (Scandinavians and Germans, Netherlanders and Anglo-Saxons). August Schleicher has explained, in a very clear genealogical form,

how the further ramifications of the Indo-Germanic race may be accurately traced in detail on the basis of comparative philology.[6]

The total number of human individuals at present amounts to between 1,300 and 1,400 millions. In our Tabular Survey 1,350 millions has been assumed as the mean number. According to an approximate estimate, as far as such a thing is possible, 1,200 millions of these are straight-haired men, only about 150 millions woolly-haired. The most highly developed species, Mongols and Mediterranese, far surpass all the other human species in numbers of individuals, for each of them alone comprises about 550 millions (compare Friedrich Müller's "Ethnography," p. 30). Of course the relative number of the twelve species fluctuates every year, and that too according to the law developed by Darwin, that in the struggle for life the more highly developed, the more favoured and larger groups of forms, possess the positive inclination and the certain tendency to spread more and more at the expense of the lower, more backward, and smaller groups. Thus the Mediterranean species, and within it the Indo-Germanic, have by means of the higher development of their brain surpassed all the other races and species in the struggle for life, and have already spread the net of their dominion over the whole globe. It is only the Mongolian species which can at all successfully, at least in certain respects, compete with the Mediterranean. Within the tropical regions, Negroes (Sudanians and Kaffres), Nubians, and Malays are in some measure protected against the encroachments of the Indo-Germani tribes by their being better adapted for a hot climate; the case of the arctic tribes of

the polar regions is similar. But the other races, which as it is are very much diminished in number, will sooner or later completely succumb in the struggle for existence to the superiority of the Mediterranean races. They are already for the most part becoming exterminated by the so-called "blessings of civilization;" also by direct conflicts and by sexual intercourse. The American and Australian tribes are even now fast approaching their complete extinction, and the same may be said of the Dravidas, Papuans, and Hottentots.

Two very important considerations must specially be borne in mind in the phylogenetic classification of the races of Men and the study of their complicated relationships. First of all, the innumerable crossings and formation of bastards which have been taking place for over twenty thousand years, owing to the sexual intercourse between the different races in their various migrations; and secondly, the special encouragement given to the separation of forms, or morphological divergence, by ancient systems of domestication or adaptation to peculiar conditions of civilized life. In both respects the circumstances of the human race have been very similar to those of our domestic animals (especially the dog), which have been domesticated for many thousands of years.

Considered from a purely morphological point of view —*i.e.* from a purely critical comparison of the manifold differences in the structure of the body, the outward shape, the formation of the skeleton, etc.—there can be no doubt that the innumerable races and varieties of our domestic dog differ in a much greater degree from one another than the different genera and species distinguished

by the zoologist in his systematic arrangement of the Dog-tribe. And yet they are generally regarded only as varieties of one single species—*Canis familiaris.* In the same way most anthropologists dogmatically and firmly hold to the so-called "unity of species" for all the races of Men, and unite them into one species, as *Homo sapiens.* However, the unprejudiced and critical inquirer, when carefully comparing them, cannot rid himself of the conviction that the morphological differences between them are much more important than those by which, for instance, the various species of bears, wolves, or cats are distinguished in the zoological system. Nay, even the morphological differences between two generally recognized species—for instance, sheep (Ovis) and goat (Capra)—are much less important than those between a Papuan and an Esquimaux, or between a Hottentot and a man of the Teutonic race. Excellent discussions on this question are contained in Paul Topinard's "Anthropology" recently published.

An historical examination of the zoological system shows us that our progressive knowledge of animal forms is leading more and more to an ever greater separation of the groups. Related species which Linnæus classed as one genus, and Cuvier as one family, now form a comprehensive order with several families and a number of genera. In the same way, the zoological system of Mammals will sooner or later separate the groups of forms we at present usually regard as "races," into "species," and the genus Homo will fall into several genera (or first into sub-genera). In that case we might then separate the Woolly-headed Man (*Ulanthropos*) and the Straight-haired Man (*Lissanthropos*) as two genera; the first genus would include our

four first-mentioned species, the second the eight last-mentioned species. It would perhaps be even more natural and practical to distinguish the four genera enumerated on the following Table: (1) Lophocomus, (2) Eriocomus, (3) Euthycomus, and (4) Euplocamus.

In now turning to the equally interesting and difficult question of the relative *connection, migration,* and *primæval home* of the twelve species of men, I must premise the remark that, in the present state of our anthropological knowledge, any answer to this question must be regarded only as a provisional hypothesis. This is much the same as with any genealogical hypothesis which we may form of the origin of kindred animal and vegetable species, on the basis of the "Natural System." But the necessary uncertainty of each special hypothesis of descent, in no way shakes the absolute certainty of the general theory of descent. Man, we may feel certain, is descended from Catarhini, or narrow-nosed apes, whether we agree with the polyphylites, and suppose each human species, in its primæval home, to have originated out of a special kind of ape; or whether, agreeing with the monophylites, we suppose that all the human species arose by differentiation from a single species of primæval man (*Homo primigenius*).

For many and weighty reasons we hold the monophyletic hypothesis to be the more correct, and we therefore assume a *single primæval home* for mankind, where he developed out of a long since extinct anthropoid species of ape. Of the five now existing continents, neither Australia, nor America, nor Europe can have been this primæval home, or the so-called "Paradise," the "cradle of the human race." Most circumstances indicate Southern Asia as the locality

SYSTEM OF THE TWELVE SPECIES OF MEN, DIVIDED INTO FOUR GENERA.

Four Genera.	*Hair on Head.*	*Form of Skull.*	*Colour of Skin.*	*Twelve Species.*
I. **Lophocomus** **Tufted and woolly-haired Man** (*Homo papuoides*)	Woolly tufts of hair, with long elliptical cross-section, black	With slanting teeth, long-headed (dolichocephalous and prognathous)	Tone yellowish-brown	1. *Lophocomus Hottentottus* South Africa
			Tone brownish-black	2. *Lophocomus Papua* New Guinea Melanesia
II. **Eriocomus** **Fleecy-haired Man** (*Homo negroides*)	A woolly fleece of hair, with elliptical cross-section, black	With slanting teeth, long-headed (dolichocephalous and prognathous)	Tone black or blackish-brown	3. *Eriocomus Cafer* South Africa
				4. *Eriocomus Niger* Sudan Negro Central Africa
III. **Euthycomus** **Straight-haired Man** (*Homo mongoloides*)	Stiff, straight circular cross-section, black	Mostly short-headed (brachycephalous); many with medium heads (mesocephalous)	Tone brown	5. *Euthycomus Malayus* Sundanesians Polynesians
			Tone yellow	6. *Euthycomus Mongolus* Asia
		Mostly with medium heads (mesocephalous); many with short heads (brachycephalous)	Tone yellow	7. *Euthycomus Arcticus* Hyperboræa
			Tone copper-red or reddish-brown	8. *Euthycomus Americanus* America
IV. **Euplocamus** **Curly-haired Man** (*Homo eranoides*)	Curly or waved, with roundish cross-section, of very various colour	With slanting teeth, long-headed (dolichocephalous and prognathous)	Tone black or black-brown	9. *Euplocamus Australis* Australia
				10. *Euplocamus Dravidas* Further India
		Mostly with medium heads (mesocephalous); many long-headed, others short-headed	Tone reddish-brown	11. *Euplocamus Nuba* North-eastern Africa
			Tone light (reddish-white or brownish)	12. *Euplocamus Mediterranus* Western Asia North Africa Europe

in question. Besides Southern Asia, the only other of the now existing continents which might be viewed in this light is Africa. But there are a number of circumstances (especially chorological facts) which suggest that the primæval home of man was a continent now sunk below the surface of the Indian Ocean, which extended along the south of Asia, as it is at present (and probably in direct connection with it), towards the east, as far as further India and the Sunda Islands; towards the west, as far as Madagascar and the south-eastern shores of Africa. We have already mentioned that many facts in animal and vegetable geography render the former existence of such a South Indian continent very probable. Sclater has given this continent the name of Lemuria, from the Semi-apes which were characteristic of it. By assuming this Lemuria to have been man's primæval home, we greatly facilitate the explanation of the geographical distribution of the human species by migration. However, this hypothesis—formerly advocated by me also—has of late years been opposed by such weighty considerations, especially from a geological point of view, that we must for the present give it up.

In this case, of all the various parts of the earth, in which the "Paradise," or place of origin of the human species, might be looked for—by far the most likely which remains is Southern Asia, and, indeed, the western part, Further India. Historical occurrences and prehistoric finds, anthropological circumstances and ethnographical combinations, palæontological discoveries and pithecological comparisons, make it seem in a high degree probable that Further India and the adjoining territory (especially the southern slopes of the

Himalayas) was the scene of the grand transformations and migrations in the organic world during the Pliocene and earliest Tertiary period. And the Mammalia—and the highest group among them, that of the Primates—appear to have been peculiarly affected by these processes of transformation. There still live among the mountains of Further India different wild tribes of men, who occupy one of the lowest stages among living races; for instance, the Todas and other tribes of the Dravidas, whom Huxley very justly classes among the Austral Negroes. Perhaps these tribes are most closely related to the long since extinct primæval Men.

We as yet know of no fossil remains of the hypothetical primæval man (*Protanthropos atavus—Homo primigenius*). But considering the extraordinary resemblance between the lowest woolly-haired men, and the highest man-like apes, which still exist at the present day, it requires but a slight stretch of the imagination to conceive an intermediate form connecting the two, and to see in it an approximate likeness to the supposed primæval men, or ape-like men. The form of their skull was probably very long, with slanting teeth; their hair woolly; the colour of their skin dark, of a brownish tint. The hair covering the whole body was probably thicker than in any of the still living human species; their arms comparatively longer and stronger; their legs, on the other hand, knock-kneed, shorter and thinner, with entirely undeveloped calves; their walk but half erect. As for the rest, if we assume a monophyletic origin for Man, the transition-form of the Protanthropos may be imagined to have been, on the whole, intermediate between South Asiatic man-like Apes and the lowest

races of the Euplocami. A great many reasons might be adduced in favour of the opinion that the primæval men of the Lissotrichous species (the primary forms of straight-haired men) were derived from South-Asiatic Anthropoids, whereas the primæval men of the Ulotrichous species (as the primary forms of the four woolly-hairy tribes) were derived from Central African man-like Apes.

Virchow, one of the few remaining eminent opponents to the theory of Man's descent from Apes, recently declared that Primæval man, or Protanthropos, was not a subject fit for serious scientific inquiry, but could be imagined only in a "dream." This "winged" word bears a suspicious resemblance to another which a very distinguished zoologist uttered thirty years ago in calling the then newly born theory of Darwin the "dream of an afternoon nap." This idea was successfully upheld throughout two decades by most coryphæi of the Berlin and Paris Academies of Science. Nevertheless, that "dream" has become a living "tree," the many-branched tree of phylogenetic sciences; a "tree of knowledge" which has already produced the most splendid fruits for all the branches of biology, and will year by year produce more.

Hand in hand with the transformation of the limbs, the gradual development of the Protanthropos, or Primæval Man, must have shown a transformation of the brain and the larynx. If actual human speech, *i.e.* the articulate language of ideas, is of monophyletic origin (as Bleek, Geiger, and others assume), then man-like apes must have already possessed the beginnings of such a language. If, on the other hand, its origin is polyphyletic (as Schleicher, F. Müller, and others maintain), then the man-like apes must

have still been without speech (Alalus), and their descendants did not acquire language until the primæval species of man had diverged into different species.

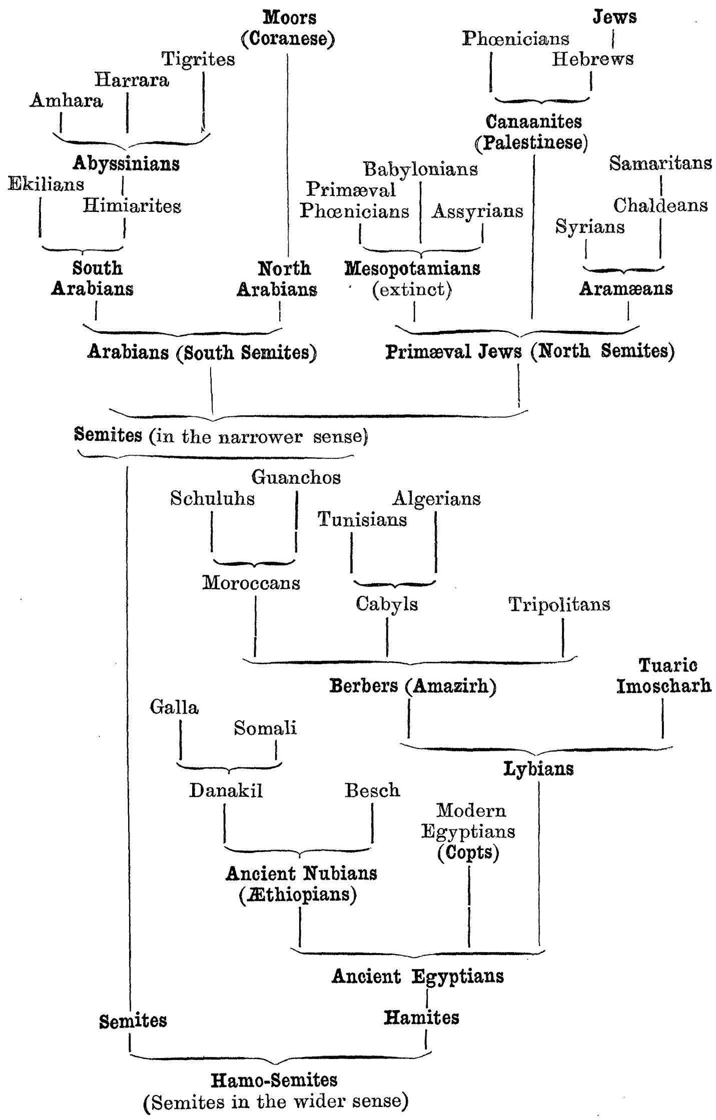
The number of primæval languages is, however, considerably larger than the number of the species of men above discussed. For philologists have hitherto not been able to trace the four primæval languages of the Mediterranean species, namely, the Basque, Caucasian, Semitic, and Indo-Germanic, to a single primæval language. As little can the different Negro languages be derived from a common primæval language; hence both these species, Mediterranean and Negro, are certainly *polyglottonic*, that is, their respective languages originated after the divergence of the speechless primary species into several races had already taken place. The Malayan species is, however, *monoglottonic;* all the Polynesian and Sundanesian dialects and languages can be derived from a common, long since extinct primæval language, which is not related to any other language on earth. All the other human species, Mongols, Arctic Men, Americans, Nubians, Dravidas, Australians, Papuans, Hottentots, and Kaffirs are likewise monoglottonic (compare p. 446). And, moreover, many important arguments favour the supposition that all these primæval languages may finally be traced back to a single common primary language as the root of all.

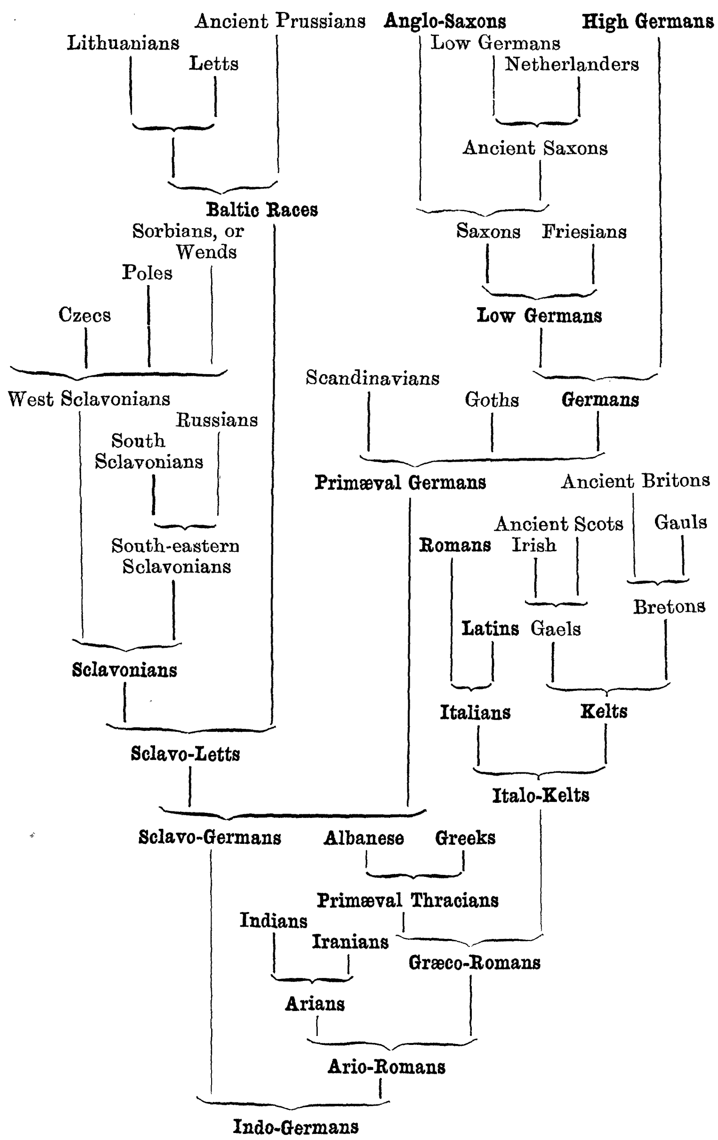
Out of speechless primæval man, whom we consider as the common primary species of all the others, there developed in the first place—probably by natural selection—various species of men unknown to us, and now long since extinct, and who still remained at the stage of speechless

ape-men (Alalus, or Pithecanthropus). Two of these species, a woolly-haired and a straight-haired, which were most strongly divergent, and consequently overpowered the others in the struggle for life, became the primary forms of the other remaining human species.

The main branch of woolly-haired men (Ulotrichi) at first spread only over the southern hemisphere, and then emigrated partly eastwards, partly westwards. Remnants of the eastern branch are the Papuans in New Guinea and Melanesia, who in earlier times were diffused much further west (in Further India and Sundanesia), and it was not until a late period that they were driven eastwards by the Malays. The Hottentots are the but little changed remnants of the western branch; they immigrated to their present home from the north-east. It was perhaps during this migration that the Negroes (Caffres and Sudanese) branched off from them; probably, however, these Eriocomi originated from another branch of the Ulotrichi.

The second main branch of primæval straight-haired men (Lissotrichi), which is more capable of development, has probably left a but little changed remnant of its common primary form—which migrated to the south-east—in the ape-like natives of Australia. It is possible that the Todas and other mountainous tribes of the Dravida species are remnants of another common primary form. Probably very closely related to these latter are the South Asiatic *primæval Malays*, or *Promalays*, which name we have previously given to the extinct, hypothetical primary form of the other six human species. Out of this unknown common primary form there seem to have arisen three diverging branches, namely, the true Malays, the Mongols,


Moors
(Coranese)
Jews
Phœnicians
Hebrews
Tigrites
Harrara
Amhara
Canaanites
(Palestinese)
Abyssinians
Babylonians
Samaritans
Ekilians
Primæval
Phœnicians
Himiarites
Assyrians
Chaldeans
Syrians
South
Arabians
North
Arabians
Mesopotamians
(extinct)
Aramæans
Arabians (South Semites)
Primæval Jews (North Semites)
Semites (in the narrower sense)
Guanchos
Schuluhs
Algerians
Tunisians
Moroccans
Cabyls
Tripolitans
Tuaric
Imoscharh
Berbers (Amazirh)
Galla
Somali
Lybians
Danakil
Besch
Modern
Egyptians
(Copts)
Ancient Nubians
(Æthiopians)
Ancient Egyptians
Semites
Hamites
Hamo-Semites
(Semites in the wider sense)


Ancient Prussians
Anglo-Saxons
High Germans
Lithuanians
Low Germans
Letts
Netherlanders
Ancient Saxons
Baltic Races
Sorbians, or Wends
Saxons
Friesians
Poles
Czecs
Low Germans
Scandinavians
West Sclavonians
Goths
Germans
Russians
South Sclavonians
Primæval Germans
Ancient Britons
Ancient Scots
Gauls
South-eastern Sclavonians
Romans
Irish
Bretons
Latins
Gaels
Sclavonians
Italians
Kelts
Sclavo-Letts
Italo-Kelts
Sclavo-Germans
Albanese
Greeks
Primæval Thracians
Indians
Iranians
Græco-Romans
Arians
Ario-Romans
Indo-Germans

and the Euplocomi; the first spread to the east, the second to the north, and the third westwards.

The primæval home, or the "Centre of Creation," of the Malays must be looked for in the south-eastern part of the Asiatic continent, or possibly in the more extensive continent which existed at the time when Further India was directly connected with the Sunda Archipelago. From thence the Malays spread towards the south-east, over the Sunda Archipelago as far as Borneo, then wandered, driving the Papuans before them, eastwards towards the Samoa and Tonga Islands, and thence gradually diffused over the whole of the islands of the southern Pacific, to the Sandwich Islands in the north, the Mangareva in the east, and New Zealand in the south. A single branch of the Malayan tribe was driven far westwards, and peopled Madagascar.

The second main branch of primæval Malays, that is, the Mongols, at first also spread in Southern Asia, and, radiating to the east, north, and north-west, gradually peopled the greater part of the Asiatic continent. Of the four principal races of the Mongol species, the Indo-Chinese must perhaps be looked upon as the primary group, out of which at a later period the other Coreo-Japanese and Ural-Altaian races developed as diverging branches. The Mongols migrated in many ways from Western Asia into Europe, where the species is still represented in Northern Russia and Scandinavia by the Fins and Lapps, in Hungary by the kindred Magyars, and in Turkey by the Osmanlis.

On the other hand, a branch of the Mongols migrated from North-eastern Asia to America, which was probably in earlier times connected with the former continent by a broad isthmus. The Arctic tribes, or Polar men, the Hyper-

boreans of North-eastern Asia, and the Esquimaux of the extreme north of America, must probably be regarded as an offshoot of this branch, which became peculiarly degenerated by unfavourable conditions of existence. The principal portion of the Mongolian immigrants, however, migrated to the south, and gradually spread over the whole of America, first over the north, later over South America.

The fourth and most important main branch of the human species, the curly-haired races of men, or Euplocami, have probably left in the Dravidas and Australians, that species of man which differs least from the common primary form of the Euplocami. The principal portion of the latter, namely, the Mediterranean species, migrated from their primæval home (Hindostan ?) westwards, and peopled the shores of the Mediterranean, South-western Asia, North Africa, and Europe. The Nubians, in the north-east of Africa, must perhaps be regarded as an offshoot of the primæval Semitic tribes, who migrated far across Central Africa almost to the western shores. The various branches of the Indo-Germanic race have deviated furthest from the common primary form of ape-like men. During classic antiquity and the middle ages, the Romanic branch (the Græco-Italo-Keltic group), one of the two main branches of the Indo-Germanic species, outstripped all other branches in the career of civilization. And it is the Germanic race, in North-western Europe and in North America, which, above all others, is in the present age spreading the network of its civilization over the whole globe, and laying the foundation for a new era of higher mental culture, in the recognition of the monistic theory of evolution.

SYSTEMATIC SURVEY OF THE TWELVE HUMAN SPECIES.

N.B.—Column A denotes the Average Number of the Population in millions. Column B shows the Degree of the Phyletic Development of the Species, thus Pr = Progressive Diffusion; Co = Comparative Stability; Re = Retrogression and Extinction. Column C denotes the Character of the Primæval Language; Mn (Monoglottonic) signifies that the Species had one Simple Primæval Language; Pl (Polyglottonic) several Primæval Languages.

Tribe.	*Human Species.*	A.	B.	C.	*Home.*
TUFT-HAIRED **Lophocomi** (about 2 millions)	1. PAPUAN	2	Re	Mn	New Guinea and Melanesia, Philippine Islands, Malacca
	2. HOTTENTOT	$\frac{1}{20}$	Re	Mn	The extreme south of Africa (The Cape)
FLEECY-HAIRED **Eriocomi** (about 150 millions)	3. KAFFRE	20	Pr	Mn	South Africa (between 30° S. Lat. and 5° N. Lat.)
	4. NEGRO	130	Pr	Pl	Central Africa (between the Equator and 30° N. Lat.)
STRAIGHT-HAIRED **Euthycomi** (about 600 millions)	5. MALAY	30	Co	Mn	Malacca, Sundanesia, Polynesia, and Madagascar
	6. MONGOL	550	Pr	Mn	The greater part of Asia and Northern Europe
	7. ARCTIC MAN	$\frac{1}{25}$	Co	Mn	The extreme north-east of Asia and the extreme north America
	8. AMERICAN	12	Re	Mn	The whole of America with the exception of the extreme north
	9. AUSTRALIAN	$\frac{1}{12}$	Re	Mn	Australia
CURLY-HAIRED **Euplocomi** (about 600 millions)	10. DRAVIDAS	34	Co	Mn	South Asia (Further India)
	11. NUBIAN	10	Co	Mn ?	Central Africa (Nubia and Fula-land)
	12. MEDITERRANEAN	550	Pr	Pl	In all parts of the world, having migrated from South Asia to North Africa and South Europe
	13. HYBRIDS OF THE SPECIES	21	Pr	Pl	In all parts of the world, but predominating in America and Asia
	TOTAL	1350			

CHAPTER XXIX.

OBJECTIONS AGAINST THE THEORY OF DESCENT.

Objections to the Doctrine of Filiation.—Objections of Faith and Reason.—Immeasurable Length of the Geological Periods.—Transition Forms between Kindred Species.—Dependence of Stability of Form on Inheritance, and of the Variability of Form on Adaptation.—Origin of very complicated Arrangement of Organization.—Gradual Development of Instincts and Mental Activities.—Origin of à priori Knowledge from Knowledge à posteriori.—The Knowledge requisite for the Correct Understanding of the Doctrine of Filiation.—Necessary Interaction between Empiricism and Philosophy.—The Anthropocentric Point of View of so-called Exact Anthropology; in Contrast with the Phylogenetic Point of View of Comparative Anthropology (on a Zoological Basis).—Practical Objections to the Consequences of the Theory of Filiation.

If I may now hope to have made the Theory of Descent seem more or less probable, and to have even convinced some of my readers of its unassailable truth, still I am by no means unconscious that, to most of them, during the perusal of my explanations, a number of objections more or less well founded must have occurred. Hence it seems absolutely necessary at the conclusion of our examination to refute at least the most important of these, and at the same time, on the other hand, once more to set forth the convincing arguments which bear testimony to the truth of the theory of development.

The objections which are raised to the doctrine of descent may be divided into two large groups: objections of faith and objections of reason. The objections of the first group originate in the infinitely varied forms of faith held by human individuals, and need not here be taken into consideration at all. For, as I have already remarked at the beginning of this book, science, as an objective result of sensuous experience, and of the striving of human reason after knowledge, has nothing whatever to do with the subjective ideas of faith, which are preached by a single man as the direct inspirations or revelations of the Creator, and then believed in by the dependent multitude. This belief, very different in different nations, only begins, as is well known, where science ends. Natural Science believes, according to the maxim of Frederick the Great, "that every one may go to heaven in his own fashion," and only necessarily enters into conflict with particular forms of faith where they appear to set a limit to free inquiry and a goal to human knowledge, beyond which we are not to venture. Now this is certainly the case here in the highest degree, for the Theory of Development applies itself to the solution of the greatest of scientific problems—that of the creation, the coming into existence of things; more especially the origin of organic forms, and of man at their head. It is here certainly the right as well as the sacred duty of free inquiry, to fear no human authority, and courageously to raise the veil from the image of the Creator, unconcerned as to what natural truth may lie concealed beneath. The only Divine revelation which we recognize as true, is written everywhere in nature, and to every one with healthy senses and a healthy reason it is given to par-

ticipate in the unerring revelation of this holy temple of nature, by his own inquiry and independent discovery.

If we, therefore, here disregard all objections to the Doctrine of Descent which may be raised by the priests of the different religious faiths, we must nevertheless endeavour to refute the most important of those objections which seem more or less founded on science, and which we grant might, at first sight, to a certain extent captivate us and deter us from adopting the Doctrine of Descent. Many persons seem to think the length of the periods of time required the most important of these objections. We are not accustomed to deal with such immense periods as are necessary for the history of the creation. It has already been mentioned that the periods, during which species originated by gradual transmutation, must not be calculated by single centuries, but by hundreds and by millions of centuries. Even the thickness of the stratified crust of the earth, the consideration of the immense space of time which was requisite for its deposition from water, taken together with the periods of elevation between the periods of depression, indicate a duration of time of the organic history of the earth which the human intellect cannot realize. We are here in much the same position as an astronomer in regard to infinite space. In the same way as the distances between the different planetary systems are not calculated by miles but by Sirius-distances, each of which comprises millions of miles, so the organic history of the earth must not be calculated by thousands of years, but by palæontological or geological periods, each of which comprises many thousands of years, and perhaps millions, or even milliards, of thousands of years.

It is of little importance how high the immeasurable length of these periods may be approximately estimated, because we are in fact unable with our limited power of imagination to form a true conception of these periods, and because we do not as in astronomy possess a secure mathematical basis for fixing the approximate length of duration in numbers. But we most positively deny that we see any objection to the theory of development in the extreme length of these periods which are so completely beyond the power of our imagination. It is, on the contrary, as I have already explained in one of the preceding chapters, most advisable, from a strictly philosophical point of view, to conceive these periods of creation to be as long as possible, and we are by so much the less in danger of losing ourselves in improbable hypotheses, the longer we conceive the periods for organic processes of development to have been. The longer, for example, we conceive the Permian period to have been, the easier it will be for us to understand how the important transmutations took place within it which so essentially distinguish the fauna and flora of the Coal period from that of the Trias. The great disinclination which most persons have to assume such immeasurable periods, arises mainly from the fact of our having in early youth been brought up in the notion that the whole earth is only some thousands of years old. Moreover, human life, which at most attains the length of a century, is an extremely short space of time, and is not suitable as a standard for the measurement of geological periods. Our life is a single drop in the ocean of eternity. The reader may call to mind the duration of life of many trees which is more than fifty times as long; for example, the dragon-trees

(*Dracæna*) and monkey bread-fruit trees (*Adansonia*), whose individual life exceeds a period of five thousand years; and, on the other hand, the shortness of the individual life of many of the lower animals, for example, the infusoria, where the individual, as such, lives but a few days, or even but a few hours, contrasts no less strongly with human longevity. This comparison brings the relative nature of all measurement of time very clearly before us. If the theory of development be true at all, there must certainly have elapsed immense periods, utterly inconceivable to us, during which the gradual historical development of the animal and vegetable kingdom proceeded by the slow transformation of species. There is, however, not a single reason for accepting a definite limit for the length of these phyletic periods of development.

A second main objection which many raise against the theory of descent, is that no *transition-forms* between the different species can be found, although according to the theory of descent they ought to be found in great numbers. This objection is partly well founded and partly not so, for there does exist an extraordinarily large number of transition-forms between living, as well as between extinct species, especially where we have an opportunity of seeing and comparing very numerous individuals of kindred species. Those careful investigators of individual species who so frequently raise this objection are the very persons whom we constantly find checked in their special series of investigations by the really insuperable difficulty of sharply distinguishing individual species. In all systematic works, which are in any degree thorough, one meets with endless complaints, that here and there species cannot be distin-

guished because of the excessive number of transition-forms. Hence every naturalist defines the limit and the number of individual species differently. Some zoologists and botanists, as I mentioned (vol. i. p. 308), assume in one and the same group of organisms ten species, others twenty, others a hundred or more, while other systematic naturalists again look upon these different forms only as varieties of a single "good" species. In most groups of forms there is, in fact, a superabundance of transition-forms and intermediate stages between the individual species.

It is true that in many species the forms of transition are actually wanting, but this is easily explained by the principle of divergence or separation, the importance of which I have already explained. The circumstance that the struggle for existence is the more active between two kindred forms the closer they stand to each other, must necessarily favour the speedy extinction of the connecting intermediate forms between the two divergent species. If one and the same species produce diverging varieties in different directions, which become new species, the struggle between these new forms and the common primary form will be the keener the less they differ from one another; but the stronger the divergence the less dangerous the struggle. Naturally, therefore, it is principally the connecting intermediate forms which will in most cases quickly die out, while the most divergent forms remain and reproduce themselves as distinct "new species." In accordance with this, we in fact no longer find forms of transition leading to those groups which are becoming extinct, as, for example, among birds, are the ostriches; and among mammals, the elephants, giraffes, Edentata, and ornitho-

rhyncus. The groups of forms approaching their extinction no longer produce new varieties, and naturally the species are what is called "good," that is, the species are distinctly different from one another. But in those animal groups where development and progress are still active, where the existing species deviate into many new species by the formation of new varieties, we find an abundance of transition-forms which cause the greatest difficulties to systematic naturalists. This is the case, for example, among birds with the finches; among mammals with most of the rodents (more especially with those of the mouse and rat kind), with a number of the ruminants and with genuine apes, more especially with the South American forms (*Cebus*), and many others. The continual development of species by the formation of new varieties here produces a mass of intermediate forms which connect the so-called "good" species, which efface their boundaries, and render their sharp specific distinction completely illusory.

The reason that this nevertheless does not cause a complete confusion of forms, nor a universal chaos in the structure of animals and vegetables, lies simply in the fact that there is a continual counteraction at work beween progressive *adaptation* on the one hand, and the *retentive* power of *inheritance* on the other hand. The degree of stability and variability manifested by every organic form is determined solely by the actual condition of the equilibrium between these two opposite functions. *Inheritance is the cause of the stability of species, adaptation the cause of their modification.* When, therefore, some naturalists say that, according to the theory of descent, there ought to be a much greater variety of forms, and others, again,

that there ought to be a much greater equality of forms, the former under-estimate the value of inheritance and the latter the value of adaptation. *The ratio of the interaction between inheritance and adaptation determines the ratio of the stability and variability of organic species* at any given period.

Another objection to the theory of descent, which in the opinion of many naturalists and philosophers is of great weight, is that it ascribes the origin of organs which act for a definite purpose to causes which are either aimless or mechanical in their operation. This objection seems to be especially important in regard to those organs which appear so excellently adapted for a certain definite purpose that the most ingenious mechanician could not invent a more perfect organ for the purpose. Such are, above all, the higher sense-organs of animals, the eye and ear. If the eyes and auditory apparatus of the higher animals alone were known to us, they would indeed cause great and perhaps insurmountable difficulties. How could we come to the conclusion that the extraordinarily great and wonderful degree of perfection and conformity to purpose which we perceive in the eyes and ears of higher animals, is in every respect attained solely by natural selection? Fortunately, however, comparative anatomy and the history of development help us here over all obstacles; for when in the animal kingdom we follow the gradual progress towards perfection of the eyes and ears, step by step, we find such a finely graduated series of improvement, that we can clearly follow the development of the most complex organs through all the stages towards perfection. Thus, for example, the eye in the lowest animal is a simple spot of pigment which

does not yet reflect any image of external objects, but at most perceives and distinguishes the different rays of light. Later, we find in addition to this a sensitive nerve; then there gradually develops within the spot of pigment the first beginning of the lens, a refractive body which is now able to concentrate the rays of light and to reflect a definite image. But all the composite apparatus for the movement of the eye and its accommodation to variations of light and distance are still absent, namely, the various refractive media, the highly differentiated membrane of the optic nerve, etc., which are so perfectly constructed in higher animals. Comparative anatomy shows us an uninterrupted succession of all possible stages of transition, from the simplest organ to the most highly perfected apparatus, so that we can form a pretty correct idea of the slow and gradual formation of even such an exceedingly complex organ. The like gradual progress which we observe in the development of the organ during the course of individual development, must have taken place in the historical (phyletic) origin of the organ.

However, it may here be remarked, that in very many cases the seeming suitability of the organization which a naïve and childlike contemplation of nature fancies it sees everywhere, and extols as "the wisdom of the Creator," is only apparently suited for the definite purpose. A more careful anatomical and physiological examination teaches us that, in very many cases, even very highly developed organs, and such as appear constructed on scientific principles, show great mechanical defects; this has been pointed out as regards the human eye by Helmholtz, one of the greatest authorities on the subject. But besides, when

we carefully compare the whole series of development of kindred forms, we see clearly that natural selection, at work in all directions without any definite plan, has slowly produced a gradual advance towards perfection, but only after many vain endeavours has it finally accomplished something partially "suitable" by accident.

Many persons when contemplating these most perfect organs—which apparently were purposely invented and constructed by an ingenious Creator for a definite function, but which in reality have arisen by the aimless action of natural selection—experience difficulties in arriving at a rational understanding of them, which are similar to those experienced by the uncivilized tribes of nature when contemplating the latest complicated productions of engineering. Savages who see a ship of the line, or a locomotive engine for the first time, look upon these objects as the productions of a supernatural being, and cannot understand how a man, an organism like themselves, could have produced such an engine. Even the uneducated classes of our own race cannot comprehend such an intricate apparatus in its actual workings, nor can they understand its purely mechanical nature. Most naturalists, however, as Darwin very justly remarks, stand in much the same position in regard to the forms of organisms as do savages to ships of the line and to locomotive engines. A rational understanding of the purely mechanical origin of organic forms can only be acquired by a thorough and general training in Biology, and by a special knowledge of comparative anatomy and the history of development. But it is just these ordinary objections of the speculative school of philosophy to this important question that are most

brilliantly refuted by the theory of selection. And, indeed, the great philosophical service of Darwin is that, after the manner of Empedocles and in the simplest way, he has solved the great problem: How can arrangements suited for a definite purpose have arisen from causes that had no definite object in view? It is the struggle for existence which incessantly and everywhere works unconsciously by natural selection, and suitably transforms organisms by means of the interaction of the laws of inheritance and adaptation. And the mechanical effects accomplished by this principle of selection are equally great and significant in the transformation of the outward shape as well as of the inward structure of the organism. In the latter we meet with it as "the functional self-formation of structures suited for a definite purpose," and Roux was the first ingeniously to describe them as such (see vol. i. p. 291). This monistic principle of "teleological mechanism," which was physiologically established by Pflüger, finally settles the old "transcendental idea of purposeness" of our dualistic school of philosophy, which has hitherto been the greatest speculative obstruction to a rational conception of nature (see vol. i. p. 299).

Among the remaining objections to the Theory of Descent, I shall here finally refer to and refute but one more, as in the eyes of many unscientific men it seems to possess great weight: How are we, from the Theory of Descent, to conceive of the origin of the mental faculties of animals, and more especially their specific expressions—the so-called instincts? This difficult subject has been so minutely discussed by Darwin in a special chapter of his chief work (the seventh), that I must refer the reader to it. We must

regard instincts as essentially the habits of the soul acquired by adaptation, and transmitted and fixed by inheritance through many generations. Instincts are, therefore, like all other habits, which, according to the laws of cumulative adaptation (vol. i. p. 252) and established inheritance (vol. i. p. 224), lead to the origin of new functions, and thus also to new forms of the organs. Here, as everywhere, the interaction between function and organ goes hand in hand. Just as the mental faculties of man have been acquired by the progressive adaptation of the brain, and been fixed by continual transmission by inheritance, so the instincts of animals—which differ from them only in quantity, not in quality—have arisen by the gradual perfecting of their mental organ, that is, their central nervous system, by the interaction of Adaptation and Inheritance. Instincts, as is well known, are inherited, but experiences also, and, consequently, new adaptations of the animal mind, are likewise transmitted by inheritance; and the training of domestic animals to different mental activities, which wild animals are incapable of accomplishing, rests upon the possibility of mental adaptation. We already know a series of examples, in which such adaptations, after they had been transmitted through a succession of generations, finally appeared as innate instincts, and yet they have only been acquired from the ancestors of the animals. Inheritance has here caused the result of training to become instinct. The characteristic instincts of sporting dogs, shepherd's dogs, and other domestic animals, and the natural instincts of wild animals, which they possess at birth, were in the first place acquired by their ancestors by adaptation. They may in this respect be compared to man's "knowledge a

priori," which, like all other knowledge, was originally acquired by our remote ancestors, "à posteriori," by sensuous experience. As I have already remarked, it is evident that "knowledge à priori" arose only by long-enduring transmission, by inheritance of acquired adaptations of the brain, out of originally empiric or experiential "knowledge à posteriori" (vol. i. p. 32).

The objections to the Theory of Descent here discussed and refuted are, I believe, the most important which have been raised against it; I consider also that I have sufficiently proved to the reader their futility. The numerous other objections which besides these have been raised against the Theory of Development in general, or against its biological part, the Theory of Descent in particular, arise either from such a degree of ignorance of empirically established facts, or from such a want of their right understanding, and from such an incapacity to draw the necessary conclusions, that it is really not worth the trouble to go further into the refutation. There are only some general points in regard to which I should like, in a few words, to draw attention.

In the first place I must observe, that in order thoroughly to understand the doctrine of descent, and to be convinced of its absolute truth, it is indispensable to possess a general knowledge of the whole of the domain of biological phenomena. *The theory of descent is a biological theory*, and hence it may with fairness and justice be demanded that those persons who wish to pass a valid judgment upon it should possess the requisite degree of biological knowledge. Their possessing a special empiric knowledge of this or that domain of zoology or botany, of anatomy or

physiology, is not sufficient; they must possess a general insight into the whole series of phenomena, at least in the case of one of the organic kingdoms. They ought to know what universal laws result from the comparative morphology and physiology of organisms, but more especially from comparative anatomy, from the individual and the palæontological history of development, etc.; and they ought to have some idea of the deep mechanical causal connection between all these series of phenomena. It is self-evident that a certain degree of general culture, and especially a philosophical education, is requisite; which is, however, unfortunately, by many persons in our day, not considered at all necessary. *Without the necessary combination of empirical knowledge with philosophical understanding of biological phenomena, it is impossible to gain a thorough conviction of the truth of the Theory of Descent.*

Now I ask, in the face of this first preliminary condition for a true understanding of the Theory of Descent, what we are to think of the confused mass of persons who have presumed to pass a written or oral judgment upon it of an adverse character? Most of them are unscientific persons, who either know nothing of the most important phenomena of Biology, or at least possess no idea of their deeper significance. What should we say of an unscientific person who presumed to express an opinion on the cell-theory, without ever having seen cells; or of one who presumed to question the vertebral theory, without ever having studied comparative anatomy? And yet one may meet with such ridiculous arrogance any day in the history of the biological Theory of Descent. One hears thousands of unscientific and but half-educated persons pass a final judg-

ment upon it, although they know nothing either of botany or of zoology, of comparative anatomy or the theory of tissues, of palæontology or embryology. Hence it happens, as Huxley well says, that most of the writings published against Darwin are not worth the paper upon which they are written.

It might be added that there are many naturalists, and even celebrated zoologists and botanists, among the opponents of the Theory of Descent; but these latter are mostly old stagers, who have grown grey in quite opposite views, and whom we cannot expect, in the evening of their lives, to submit to a reform in their conception of the universe, which has become to them a fixed idea. The biologists of the younger generation, men who have grown up since the appearance of Darwin's work (1859), are all convinced of the truth of the doctrine of Filiation.

It is, moreover, expressly to be remarked, that not only a general insight into the whole domain of biological phenomena, but also a philosophical understanding of it, are the necessary preliminary conditions for becoming convinced of and adopting the Theory of Descent. Now we shall find that these indispensable preliminary conditions are, unfortunately, by no means fulfilled by the majority of naturalists of the present day. The immense amount of empirical facts with which the gigantic advances of modern natural science have recently made us acquainted has led to a prevailing inclination for the special study of single phenomena and of small and narrow domains. This causes the knowledge of other paths, and especially of Nature as a great comprehensive whole, to be in most cases completely neglected. Every one with sound eyes and a microscope,

together with industry and patience for study, can in our day attain a certain degree of celebrity by microscopic "discoveries," without, however, deserving the name of a naturalist. This name is deserved only by him who not merely strives to know the individual phenomena, but who also seeks to discover their causal connection. Even in our own day, most palæontologists examine and describe fossils without knowing the most important facts of embryology. Embryologists, on the other hand, follow the history of development of a particular organic individual, without having an idea of the palæontological history of the whole tribe, of which fossils are the records. And yet these two branches of the organic history of development—ontogeny, or the history of the individual, and phylogeny, or the history of the tribe—stand in the closest causal connection, and the one cannot be understood without the other. The same may be said of the systematic and the anatomical part of Biology. There are even now, in zoology and botany, many systematic naturalists who work with the erroneous idea that it is possible to construct a natural system of animals and plants simply by a careful examination of the external and readily accessible forms of bodies, without a deeper knowledge of their internal structure. On the other hand, there are anatomists and histologists who think it possible to obtain a true knowledge of animal and vegetable bodies merely by a most careful examination of the inner structure of the body of some individual species, without the comparative examination of the bodily form of all kindred organisms. And yet here, as everywhere, the internal and external factors, to wit, Inheritance and Adaptation, stand in the closest mutual relation, and the indi-

vidual can never be thoroughly understood without a comparison of it with the whole of which it is a part. To those one-sided specialists we should like in Goethe's words to say—

> "We must, in contemplating Nature,
> Part and Whole alike give heed to:
> Nought is inward, nought is outward,
> For the inner is the outer." *

And again—

> "Nature has neither shell nor kernel,
> For she is ever All in All." †

What is even more detrimental to the general understanding of nature as a whole than this one-sided tendency, is *the want of a philosophical culture;* and this applies to most of the naturalists of the present day. The various errors of the earlier speculative nature-philosophy made during the first thirty years of our century, have brought the whole of philosophy into such bad repute with the exact empirical naturalists, that they live in the strange delusion that it is possible to erect the edifice of natural science out of mere facts, without their philosophic connection; in short, out of mere knowledge, without the understanding of it. But a purely speculative and absolutely philosophical system, which does not concern itself with the indispensable foundation of empirical facts, becomes a castle in the air, which the first real experiment throws to the winds; there is no dearth of such in Germany (for example, Hegel). On the

* "Müsset im Naturbetrachten
Immer Eins wie Alles achten:
Nichts ist drinnen, Nichts ist drauszen,
Denn was innen, das ist auszen."

† "Natur hat weder Kern noch Schale,
Alles ist sie mit einem Male."

other hand, a purely empirical system, constructed of nothing but facts, remains a disorderly heap of stones, which will never deserve the name of an edifice. Examples of the last species may be found in the collected ethnographical works of the well-known "ethnologist" Bastian; a motley confusion of notes flung together, anything like a leading idea being carefully avoided in the disorderly enumeration of facts. Bare facts established by experience are nothing but rude stones, and without their thoughtful valuation, without their philosophic connection, no science can be established. As I have already tried to impress upon my reader, the *strong edifice of true monistic science*, or what is the same thing, the *Science of Nature, exists only by the closest interaction, and the reciprocal penetration of philosophy and empirical knowledge.*

This lamentable estrangement between science and philosophy, and the rude empiricism which is nowadays unfortunately praised by most naturalists as "exact science," have given rise to those strange freaks of the understanding, to those gross insults against elementary logic, and to that incapacity for forming the simplest conclusions which one may meet with any day in all branches of science, but especially in zoology and botany. It is here that the neglect of a philosophical culture and training of the mind, directly avenges itself most painfully. It is not to be wondered at that the deep inner truth of the Theory of Descent remains a sealed book to those rude empiricists. As the common proverb justly says, "they cannot see the wood for the trees." It is only by a more general philosophical study, and especially by a more strictly logical training of the mind, that this sad state of things can be remedied.

The most striking and most numerous examples of this want of sound logic are still met with in the domain of so-called "exact anthropology," and as this young science, on the one hand, promises much for the future, and, on the other, as the objections it raises against the theory of descent are directed against its most important deduction—the derivation of Man from apes—it will be appropriate here critically to examine these objections somewhat more closely. As a conspicuous example of this tendency, I select Johannes Ranke's large work, in two volumes, containing over a thousand illustrations, entitled "Man" ("Der Mensch"), and published in Leipzig in 1887. The point of view from which this "exact anthropologist" judges the nature of man, and sets it before a cultured public in an eminently popular form, Ranke himself, in his preface, characterizes as clearly as could be desired in the following sentence: "The foundation upon which all the conclusions in this work are based, is formed by the generally recognized proposition, that logically the whole animal world—in regard to bodily structure—constitutes an ideal unity, at the head of which stands Man. In this sense the animal kingdom is, as it were, Man resolved into his parts ('*der zergliederte Mensch*'), and Man the paradigm of the whole animal kingdom."

This fundamental principle of Ranke's, which, according to his own statement, forms the basis of all his anthropological considerations, is not a new one; it is the very old point of view of the anthropocentric conception of the universe, according to which Man is the centre and final object of all life on earth, and that the rest of nature was created only to serve this "lord of the universe"

As is well known, this conception is intimately connected with the geocentric delusion that the earth is the fixed centre of the universe, round which centre sun, moon, and stars revolve; those, therefore, who adopt the first must, to be consistent, accept the latter view also, which has recently been again set forth with so much success by Pastor Knack. According to our absolutely opposite opinion, the geocentric delusion was as definitely refuted by Copernicus and Newton, as the anthropocentric delusion has been by Lamarck and Darwin.

What, however, is new and interesting in Ranke's fundamental program, is his assertion that this anthropocentric principle is a "generally recognized proposition." In the first place, however, it would surely have to be recognized by zoologists, for it is they who have made the animal kingdom their special study, and hence should by rights know it best. I myself have been at work for close upon thirty years as teacher of zoology, and believe I have obtained a certain insight into the animal kingdom; and having, further, for six years previously studied medicine, zealously endeavouring to acquire a deeper knowledge of the natural history of man, I consider myself entitled to having a certain amount of authority even in anthropology. I maintain, therefore—and feel assured that all our present zoologists will unanimously agree with me—that Ranke's first and "generally recognized principle" is absolutely false, and that the exact reverse is true. Neither is the animal kingdom "Man resolved into his parts," nor is "Man the paradigm of the whole animal kingdom." Of the ten tribes of the animal kingdom whose individual history we have been examining, five—and, indeed, the five most

rich in forms—have no relation to Man whatever, namely, the Sponges, Cnidaria, Molluscs, Echinoderma, and Articulata. Of the five others, four only possess a morphological and phylogenetic connection with Man, in so far as, probably, single forms of every tribe belong to the series of the ancestors of Man, or at least to his nearest blood-relations; for instance, the Gastræada, the earliest Platodes, some groups among the Helminthes, and the Copelata among the Tunicates. Only one single tribe of the animal kingdom can, in a certain sense, be considered "dismembered Man," and Man the "paradigm" of this tribe, and that is the tribe of the Vertebrates. But this "unity" is assuredly not at all an "ideal" one, as Ranke maintains, but a very real one, that is, phylogenetic; Man is only a single, small, and but lately developed branch of the mighty Vertebrate tribe, the numerous branches of which—with thousands of different offshoots—have developed independently in every direction, and the majority of these have no "ideal" or indeed any sort of connection with Man.

This is our present phylogenetic fundamental conception of Man, and it stands in the most absolute opposition to the anthropocentric conception represented by Ranke. Only one of the two can be the true. Of course the anthropocentric conception of the universe flatters the vanity and imagination of Man in the highest degree; it is, therefore, not to be wondered at that this long since obsolete illusion, refuted by Lamarck eighty years ago, should still find most grateful acceptance with our anthropological public. These "exact anthropologists," vying with theologians and dualistic philosophers in painting to their fellow-men "Man's position *above* all nature" in the most brilliant

colours, and representing the gap between "Man's kingdom" and the animal kingdom as impassable, resemble those flatterers who, in bygone centuries, in the courts of princes, and with the best result, pointed to the "divine nature" of the ruling class, as opposed to the "profane" people. It is another question as to whether the principle upheld by Ranke and his associates is true, and whether it can be scientifically established. All the zoologists of our day—and they alone can judge of such a zoological question—will join me in maintaining the contrary, and will bear witness that Ranke's "foundation for all his conclusions" is absolutely untenable.

From these circumstances it may at once be gathered how utterly false in all its details must be the image of Man, and his "position in Nature," which Ranke gives in his work, with its numerous illustrations. All the zoological facts which might throw light on the subject, and which, to every logical mind, bear witness to Man's descent from a series of other vertebrates, are either passed over in silence, or so distorted that the unbiassed reader must infer from the work the very opposite of the truth. Besides this, all the various points which create difficulties to the theory of descent, or which appear to contradict Man's descent from apes, are entered into in detail, and brought prominently forward. The numerous objections which Ranke raises against the theory of filiation, certainly, in most cases, exhibit as great a want of sound logic as they do of the indispensable preliminary knowledge in zoology.

This examination of Ranke's work on "Man," and my earnest, vehement protest against his anthropocentric tendency, which so completely distorts the truth, seemed

specially called for here, because, owing to its excellent illustrations, and the rich collection of interesting facts it contains, the book has found its way among a very large circle of readers. The book forms part of the well-known edition of Brehm's "Animal Life," the largest and best-illustrated popular Natural History of our day. It is much to be regretted that the publishers should have placed the most important part of this splendid work, which enjoys such a wide circulation, into the hands of one of the most vehement opponents of the theory of development. This anthropological part stands thus in striking contrast to the other parts; to Friedrich Ratzel's admirable "Ethnography," to A. Kerner's suggestive "Plant Life," and to Melchior Neumayr's excellent "History of the Earth." For while the reader, in all of the above admirable works, is led by the doctrine of development to the true understanding of phenomena, in Ranke's work on "Man" exactly the reverse is the case; he finds a rich collection of wonderful phenomena, the causes of which are made to appear explicable only by supernatural miracles.

How different the results of our present "exact anthropology" appear in the light of the theory of descent, the unprejudiced reader may gather from Paul Topinard's already mentioned, admirable work on "Anthropology," also from Huxley's well-known "Evidences as to Man's Place in Nature," and Wiedersheim's able little treatise on "The Structure of Man as a Proof of his Past." I have myself, in my "Anthropogeny," endeavoured to prove that the fundamental law of biogeny applies also to Man, and that the human race has certainly arisen out of a long series of other Vertebrates by gradual transformation, just as,

according to the same laws, the gradual transformation of the egg into the human embryo occurs in the ontogeny of Man precisely as in the case of the other Vertebrates. In my opinion it is just these very ontogenetic facts that are of the highest value, and all the objections raised against them are as futile and untenable as the objections formerly brought forward against the theory of development.

Another series of objections raised against the theory of filiation are of a practical nature, not theoretical; they do not question its scientific truth or basis, but dread the practical consequences which the spread of such ideas may have upon our mental culture and general civilization. Many persons are of the opinion that such doctrines will shake the foundations of our civilization, and more especially affect our morality. These fears are much the same as have always been raised against any great advance in science. The fruits from the "tree of knowledge" have ever been forbidden; and the priesthood, who fancied themselves alone in possession of the truth, have ever carefully reserved these for their own benefit, and to the detriment of the rest of humanity. When Copernicus, three hundred years ago, did away with the geocentric delusion, and founded our present system of the universe, a storm of indignation arose, and the Church hurled the same anathemas against it, as it did thirty years ago when Darwin withdrew the last support from the anthropocentric delusion.

The history of civilization has taught us how unfounded such fears have ever been. The discovery and dissemination of every great truth must naturally be followed by the destruction of the existing errors; and the greater the estimation in which these errors have been held, the more

dangerous must the influence of the innovation appear. However, sooner or later it becomes clear that the dreaded danger has introduced the most beneficent results. For every deep wound which the advance of science causes to existing circles of culture, it at the same time carries with it the best remedy; and from the altar where any supposed truth has fallen, there arise ten new and better kinds of knowledge.

Hence we may consider it as certain that the unparalleled advance made in our knowledge of Nature, introduced by the doctrine of filiation, must sooner or later be followed by the most beneficent results for the practical life of man. But even though this conviction did not possess the certainty which we claim for it, we ought not to raise an objection against the truth or against our duty to further it. For the task which science has ever in view is to recognize truth for its own sake, heedless of what results the human mind may infer from it. In the struggle of human minds the victory will eventually remain with what is best.

CHAPTER XXX.

PROOFS OF THE TRUTH OF THE THEORY OF DESCENT.

Ten Groups of Biological Facts as Proofs of the Doctrine of Filiation : Facts of Palæontology, Ontogeny, Morphology, Tectology, Taxonomy, Dysteleology, Physiology, Psychology, Chorology, Œcology.—Mechanico-causal Explanation of these Ten Groups of Phenomena by the Theory of Descent.—Inner Causal Connection between them all.—Direct Proof of the Theory of Selection.—Its Relation to the Pithecoid Theory.—Induction and Deduction.—Proofs of the Derivation of Man from Apes : Zoological Facts.—Gradual Development of the Human Mind, in Connection with that of the Body.—Human Soul and Animal Soul.—Glance at the Future : Victory of the Monistic Philosophy.

HAVING completed my discussion of the Doctrine of Evolution, I endeavoured in my last chapter to bring forward and to refute the more important of the objections that have been raised against the theory. Hence it will now be desirable once more to look back and to set forth the proofs which speak in favour of the doctrine, and which, in their totality, form an irrefutable testimony of the truth of the theory of evolution, more especially of its biological part—the theory of descent. The more the doctrine of filiation has of late years made way for itself, and the more all our thoughtful younger naturalists, and all truly biologically educated philosophers, have become convinced of its irrefragable truth, the louder have its opponents called for actual proofs. The same persons who, shortly after the publication of

Darwin's work, declared it to be a "groundless, fantastic system," an "arbitrary speculation," an "ingenious dream," now find themselves obliged to admit that the theory of descent certainly is a scientific "hypothesis," but that it still remains to be "proved." When such remarks are made by persons who do not possess the requisite empirico-philosophical culture, nor the necessary knowledge in comparative anatomy, embryology, and palæontology, we take their remarks for what they are worth, and refer them to the study of those sciences. But when similar remarks are made by acknowledged specialists, by teachers of zoology and botany, who certainly ought to possess a general insight into the whole domain of their science, or who are actually familiar with the facts of those scientific domains, then we are really at a loss what to say. Those who are not satisfied with the treasures of our present empirical knowledge of nature as a basis on which to establish the Theory of Descent, will not be convinced by any other facts which may hereafter be discovered.

It is obvious that we can conceive no circumstances which would furnish stronger or more complete testimony to the truth of the doctrine of filiation than is even now to be observed, for example, in the well-known facts of comparative anatomy and ontogeny. All the great groups of facts and all the comprehensive series of phenomena of the most different domains of biology, can only be mechanically explained and understood by the theory of evolution; without it they remain completely inexplicable and unintelligible. In their inner causal connection they all prove the theory of descent to be the greatest inductive law of Biology. And it is precisely this inner, monistic, and

mechanical causal-nexus that constitutes its substantial power. The empirical foundations of this inductive law, the firm pillars upon which the edifice of Descent is erected, are formed by the following ten groups of biological facts:—

(1) *The palæontological facts:* the phenomena of the appearance of fossils and the gradual historical succession of the extinct species and groups of species; the phenomena of the palæontological change of species, and more especially the progressive differentiation and perfecting of the animal and vegetable groups in the successive periods of the earth's history. The mechanical explanation of these palæontological phenomena is furnished by the history of the tribe, that is, by phylogeny.

(2) *The ontogenetic facts:* the phenomena of the individual development or ontogeny, the individual history of organisms (embryology and metamorphology); the slow and regular changes in the gradual development of the germ and of its several organs, especially the progressive differentiation and perfecting of the organs and parts of the body in the successive periods of the individual development. The meehanical explanation of these ontogenetic facts is given by the fundamental biogenetic law.

(3) *The morphological facts:* the phenomena in the domain of the comparative anatomy of organisms; the essential agreement of the related groups of forms, in spite of the greatest difference in the external form in the different species. The mechanical explanation of these morphological facts is given by the theory of descent, inasmuch as it traces the agreement of the inner structure to inheritance, and the external inequalities of the form of body to adaptation.

(4) *The tectological facts:* the phenomena in the domain of the science of tissues and the kindred branches of the science of structures; the regular construction of the many-celled organisms of cells and tissues, as well as of organs of different orders. The mechanical explanation of these histological phenomena is given by the theory of cells, inasmuch as, on the one hand, it proves the constant one-celled nature of the Protista, and on the other derives the many-celled Histons from them.

(5) *The taxonomic facts:* the phenomena in the natural grouping of all the different forms of animals and plants, their division into numerous smaller and larger groups, arranged beside and above one another; the form-relationships and connections between the species, genera, families, orders, classes, etc.; more especially, however, the arboriform branching character of the natural system, which is the spontaneous result of a natural arrangement and classification of all these graduated groups or categories. The mechanical explanation of this variously graduated form-relationship is given by the supposition that it is the expression of actual blood-relationship; the tree-shape of the natural system can only be explained as the actual pedigree of organisms.

(6) *The dysteleological facts:* the exceedingly interesting phenomena of the suppressed and degenerated, aimless and inactive parts of the body, the abortive or rudimentary organs; the fact that, in the suitably constructed body, there exist in almost all of the higher organisms unsuitable parts, arranged for a definite purpose, but incapable of exercising their function. The mechanical explanation of these is obtained from dysteleology, or the theory of purposelessness,

one of the most important and interesting parts of the theory of selection; it explains the degeneration and suppression of the rudimentary organs by want of exercise and disuse.

(7) *The physiological facts:* the phenomena of adaptation (nutrition) and inheritance (propagation), in connection with the change of substance and growth, of the movement and the sensation of living creatures. The mechanical explanation of all these vital phenomena is offered by comparative physiology, inasmuch as it traces them back to the laws of physics and chemistry.

(8) *The psychological facts:* the phenomena of soul-life in the wider and narrower sense, in the cell-soul of the Protista as well as in the brain-soul of the Histons; the regular occurrence of organic irritability in all cells, and of will-activity, sensation and consciousness. The mechanical explanation of all these "activities of the soul" is offered by monistic psychology, inasmuch as it assumes the cell-soul of the Protista as a foundation, and derives the composite soul-functions of the Histons from it, according to the fundamental principles of "cellular psychology."

(9) *The chorological facts:* the phenomena in the topographical distribution of the organic species, their geographical and topographical distribution over the surface of the earth; over the various countries of the earth and in the different climates; over the heights of mountains and the depths of the ocean. The mechanical explanation of these chorological phenomena is furnished by the theory of migration—the assumption that every species of organism proceeds from a so-called "centre of creation" (more correctly a "primæval home" or "native place"), *i.e.* from a

single locality where it originated but once, and from which it spread abroad either actively or passively.

(10) *The œcological facts:* the extremely varied and complex phenomena, which show us the relations of organisms to the surrounding outer world, to the organic and anorganic conditions of existence; the so-called "economy of nature," the correlations between all organisms which live together in one and the same locality. The mechanical explanation of these œcological phenomena is furnished by the theory of the adaptation of organisms to their surroundings, their transformation by the struggle for existence, by parasitism, etc. Upon a superficial examination, these phenomena of the "economy of nature" appear to be the wise arrangements of a creator acting for a definite purpose, but upon a more careful investigation they prove to be the necessary results of mechanical causes (adaptations).

Every unbiassed naturalist capable of forming an opinion, and who penetrates into one of these ten large domains of biology, and endeavours to account for the wealth of facts from natural causes, will become convinced that this is possible only by means of the theory of descent; all these facts, therefore, afford so many proofs of the truth of the theory. And this becomes even more evident still by the logical connection between these different series of phenomena, by the knowledge of the mechanical causal-nexus that exists between them. We need here only remind the reader of the inner connection between palæontology and ontogeny, between morphology and the systematic classification, between physiology and psychology, between chorology and œcology.

In doing this we must specially emphasize the fact that the inner causal connection between the phenomena of all these biological domains is purely a mechanical one, just as their explanation by the theory of descent is a mechanical one; *i.e.* the question concerns mere working-causes (*causæ efficientes*), not by any means causes with a purpose (*causæ finales*). Hence they all serve as much in firmly establishing the monistic system of philosophy as in definitely refuting the dualistic conception of the universe.

On account of the grand proofs just enumerated, we should have to adopt Lamarck's Theory of Descent for the explanation of biological phenomena, if we did not possess Darwin's Theory of Selection. The former is so completely and directly proved by the latter, and established by mechanical causes, that there remains nothing to be desired. The laws of *Inheritance* and *Adaptation* are universally acknowledged physiological facts, the former traceable to propagation, the latter to the nutrition of organisms. On the other hand, the struggle for existence is a biological fact, which with mathematical necessity follows from the general disproportion between the average number of organic individuals and the numerical excess of their germs. But as Adaptation and Inheritance in the struggle for life are in continual interaction, it inevitably follows that natural selection, which everywhere influences and continually changes organic species, must, by making use of divergence of character, produce new species. Its influence is further especially favoured by the active and passive migrations of organisms, which take place everywhere. If we give these circumstances due consideration, the continual and gradual modification or transmutation of organic

species will appear as a biological process, which must, according to causal law, of necessity follow from the actual nature of organisms and their mutual correlations.

That even the origin of man must be explained by this general organic process of transmutation, and that it is simply as well as naturally explained by it, has, I believe, been sufficiently proved in my last chapter. I cannot, however, avoid here once more directing attention to the inseparable connection between this so-called "theory of apes," or "pithecoid theory," and the whole Theory of Descent. If the latter is the greatest inductive law of biology, then it of necessity follows that the former is its most important deductive law. They stand and fall together. As all depends upon a right understanding of this proposition, which in my opinion is very important, and which I have therefore several times brought before the reader, I may be allowed to explain it here again by a few examples.

In all mammals known to us the centre of the nervous system is the spinal marrow and the brain; from this we draw the general inductive conclusion that all mammals, without exception—those extinct, together with all those living species as yet unknown to us, as well as the species which we have examined—possess alike a brain and spinal marrow. Now, if there be discovered in any part of the earth a new species of mammal—for instance, a new species of marsupial, or a new species of deer, or a new species of ape—every zoologist knows with certainty at once, without having examined its inner structure, that this species must likewise possess a brain and spinal marrow. Not a single naturalist would ever think of supposing that the central

nervous system of this new species of mammal could possibly consist of a ventral cord with an œsophageal collar as in the Articulata, or of scattered pairs of ganglia as in the Molluscs. This completely certain and safe conclusion, which is not based upon any direct experience, is a *deductive conclusion.* In all mammals, further, at an early stage of the embryonic development, a bladder-shaped allantois is formed. In Man alone this had hitherto not been observed. Notwithstanding this, in my "Anthropogeny," published in 1874, I maintained its existence in Man also, and was therefore accused of having "falsified science." Only one year afterwards, in 1875, the bladder-shaped allantois was really observed in the human embryo, and hence my deduction based upon induction was actually confirmed. By the same logical procedure—as I have already stated in a former chapter—Goethe, from the comparative anatomy of mammals, established the general inductive conclusion that they all possess a mid jawbone, and afterwards drew from it the special deductive conclusion that man, who in all other respects does not essentially differ from other mammals, must also possess a like mid jawbone. He maintained this conclusion without having actually seen the human mid jawbone, and only proved its existence subsequently by actual observation.

The process of *induction* is a logical method of forming conclusions from the special to the general, by which we advance from many individual experiences to a general law; *deduction,* on the other hand, draws a conclusion from the general to the special, from a general law of nature to an individual case. Thus the Theory of Descent is, without doubt, a great inductive law, empirically based upon

all the biological experience cited above; the pithecoid theory, on the other hand, which asserts that man has developed out of lower, and in the first place out of ape-like mammals, is a deductive law inseparably connected with the general inductive law.

The pedigree of the human race, the approximate outlines of which I gave in the last chapter but one, of course remains in detail (like all the pedigrees of animals and plants previously discussed) a more or less approximate general genealogical hypothesis. I consider it as certain that many single suppositions in the chain of my hypotheses are erroneous, and that the progressive phylogeny of Man will at a future date represent many of the twenty-five assumed ancestral stages differently. This, however, does not affect the application of the theory of descent to man. Here, as in all investigations on the derivation of organisms, we must clearly distinguish between the general theory of descent and the special hypotheses of descent. The general theory of descent claims full and lasting value, because it is an inductive law, based upon all the whole series of biological phenomena and their inner causal connection. Every special hypothesis of descent, on the other hand, has its special value determined by the existing condition of our biological knowledge, and by the extent of the objective empirical basis upon which we deductively establish this particular hypothesis by subjective conclusions. Hence, all the individual attempts to obtain a knowledge of the pedigree of any one group of organisms possesses but a temporary and conditional value, and any special hypothesis relating to it will become the more and more perfect the greater the advance we make in the comparative anatomy,

ontogeny, and palæontology of the group in question. The more, however, we enter into genealogical details, and the further we trace the separate offshoots and branches of the pedigree, the more uncertain becomes our special *hypothesis* of descent on account of the incompleteness of our empirical basis. This, however, does no injury to the certainty of the general *theory* of descent. Accordingly, there can be no doubt that we can and must, with full assurance, regard the derivation of man—in the first place, from ape-like forms, further back, from lower mammals, and thus continually further back to lower stages of the vertebrata down to their lowest invertebrate roots, nay, even down to a simple plastid—as a general *theory*. On the other hand, the special tracing of the human pedigree, the closer definition of the animal forms known to us, which either actually belong to the ancestors of man, or at least stand in very close blood-relationship to them, will always remain a more or less approximate *hypothesis* of descent, all the more in danger of deviating from the real pedigree the nearer it endeavours to approach it by searching for the individual ancestral forms. This state of things results from the immense gaps in our palæontological knowledge, which can, under no circumstances, ever attain to even an approximate completeness.

A thoughtful consideration of this important circumstance at once furnishes the answer to a question which is commonly raised in discussing this subject, namely, the question of scientific proofs for the animal origin of the human race. Not only the opponents of the Theory of Descent, but even many of its adherents who are wanting in the requisite philosophical culture, look too much for "signs" and for

special empirical advances in the science of nature. They await the sudden discovery of a human race with tails, or of a talking species of ape, or of other living or fossil transition-forms between man and the ape, which shall fill the already narrow chasm between the two, and thus empirically "prove" the derivation of man from apes. Such special manifestations, were they ever so convincing and conclusive, would not furnish the proof desired. Unthinking persons, or those unacquainted with the series of biological phenomena, would still be able to maintain the objections to those special testimonies which they now maintain against our theory.

The absolute certainty of the Theory of Descent, even in its application to man, is built on a more solid foundation; and its true inner value can never be tested simply by reference to individual experience, but only by a philosophical comparison and estimation of the treasures of all our biological experiences. The inestimable importance of the Theory of Descent is surely based upon this, that the theory follows of necessity (as a general inductive law) from the comparative synthesis of all organic phenomena of nature, and more especially from the triple parallelism of comparative anatomy, of ontogeny, and phylogeny; and the pithecoid theory under all circumstances (apart from all special proofs) remains as a special deductive conclusion which must of necessity be drawn from the general inductive law of the Theory of Descent.

In my opinion, all depends upon a right understanding of this philosophical foundation of the Theory of Descent and of the pithecoid theory which is inseparable from it. Every unprejudiced and unbiassed naturalist, with sound

judgment and sufficient preliminary acquaintance with the biological domain, must nowadays necessarily come to the same conclusion; for if, in fact, the theory of evolution be true, if the various species of animals have not been created by miracles, but have developed in a natural way from lower forms, then Man likewise can be no exception to the rule; then Man, too—who, according to his organization, is a mammal—has arisen phylogenetically from the class of mammals; and as, of all mammals, the Apes are by far the most like Men (the differences in the structure of the body of Men and the Anthropoid Apes being much less than the differences between Anthropoid Apes and the lower Apes), it is now an indubitable fact "that Man is descended from Apes." But, of course, it is self-evident that not a single living form of ape can be considered as the ancestor of the human race; this ancestor must have belonged to a long since extinct species of Anthropoid, as I have already frequently and expressly stated.

Naturally, the numerous opponents to the Theory of Descent, and, above all, the theologians—who fancy the existence of their Church imperilled by such ideas—do all in their power to refute that weighty proposition; and as no scientific arguments can be found to oppose it, scientific authorities are called upon to annihilate the hateful "false doctrine." Of these scientific authorities the one most frequently appealed to at present is the famous pathologist, Rudolf Virchow. Some years ago he delivered, in Berlin, his celebrated address which culminated with the declaration, "it is absolutely certain that Man is not descended from Apes." Now, as this statement unquestionably denounces our main proposition as distinctly as we affirm its truth, and

as Virchow's words are still daily cited as an "absolute refutation of the Ape-theory," it seems appropriate here to examine it somewhat more closely, and to test its arguments.

The word "Ape," as every one knows, signifies a definite form of mammal, and, moreover, a group composed of numerous similar genera and species. This group is by all zoologists unanimously considered to be a natural order of the class of Mammalia, and very sharply distinguished by definite characteristics. All zoologists are equally agreed in classing this order of Apes, together with the group of forms represented by Man, in the main division of the Primates, which Linnæus' discerning mind established a hundred and fifty years ago. For Man is not only in outward form far more like the Apes than any of the other animals, but he resembles them in the most important peculiarities of the inward structure of the body, in the characteristic formation of the skull and brain, of the jaw and of the placenta, in the peculiar formation of the heart, of the intestinal tube, of male and female organs, etc. Mark me, Man is not in all of these respects absolutely like any of the present living Apes (as little as Mediterranese and Negroes, Mongols and Papuans, are entirely alike), but the differences between Man and the highest Apes are far less than the differences between the latter and the lower Apes. This significant "law of Huxley" still stands unshaken in its full extent, in spite of all the attacks which have been directed against it by our opponents for the last five and twenty years. Nay, as we have already shown, it can be even more definitely applied within the group of the Catarhini, inasmuch as Man, in

every morphological respect, stands much closer to the Anthropoids than these do to the Cynopitheca. For this reason one of the best authorities on the Anthropomorpha, Robert Hartmann,[67] classes these man-like apes with Man in one family, and contrasts all the other Apes, Catarhini and Platyrhini, to them as a second family.

These are zoological facts, and facts of the weightiest importance. They, together with the well-known facts of comparative ontogeny, form the most convincing proofs of the "descent of Man from Apes" imaginable. If their power of proof is not sufficient, then we must assuredly despair of being able to give a rational answer to that "question of all questions." All the most eminent zoologists of our day have unanimously come to the conviction that this question is, in fact, comparatively simple and easy to answer compared with the much more intricate phylogenetic questions which, for instance, concern the origin of the elephants, the rock-conies, the semi-apes, etc. And yet no zoologist any longer doubts that all these mammals are derived from one and the same primary form.

In view of this state of affairs, we zoologists, recognized as authorities on the subject, may surely ask, How can many so-called anthropologists still maintain that there exist no sort of actual proofs of the "Derivation of Man from Apes"? How can Virchow, Ranke, and others, who are not zoologists, in the speeches they annually deliver at anthropological and other congresses, continue to declare that this "Pithecoid thesis" is an empty hypothesis, an unproved assertion, and a mere dream of the philosophers of nature? How can these anthropologists still continue to ask for "certain proofs" of this thesis, when proofs with all the clearness

that could be desired lie before them, and are unanimously recognized by all zoologists.

As regards Virchow's often quoted declarations against the Pithecoid thesis, they have obtained great favour in wide circles, only because of the high authority this famous naturalist enjoys in an entirely different domain of science. His "cellular pathology," his ingenious application of the cell-theory to the whole province of medicine, introduced a grand advance in that branch of science thirty years ago. This great and lasting service rendered by him has, however, no connection whatever with the unyielding and negative position which, unfortunately, Virchow persists in assuming towards the doctrine of evolution.

But although the derivation of Man from Apes can no longer be questioned from a zoological point of view, still it is frequently maintained that this applies only to the bodily, not to the mental development of man. Now, as we have hitherto been occupied only with the former, it is perhaps necessary here to cast a glance at the latter in order to show that it is also subject to the great general law of development. In doing this it is, above all, necessary to recollect that body and mind can, in fact, never be considered as distinct, but rather that both sides of nature are inseparably connected, and stand in the closest interaction. As even Goethe has clearly expressed it, "matter can never exist and act without mind, and mind never without matter." The artificial discord between mind and body, between force and matter, which was maintained by the erroneous dualistic and teleological philosophy of past times, has been disposed of by the advances of natural science, and especially by the theory of development, and can no

longer exist in face of the prevailing mechanical and monistic philosophy of our day. How human nature, and its position in regard to the rest of the universe, is to be conceived of according to the modern view, has been minutely discussed by Radenhausen in his excellent " Isis " and " Osiris,[33] and by Carus Sterne in his admirable history of the development of the universe, "The Coming into Existence and the Passing from it." [26]

With regard to the origin of the human mind or the soul of man, we, in the first place, perceive that in every human individual it develops from the beginning, step by step and gradually, just like the body. In a newly born child we see that there exist neither an independent consciousness, nor in fact clear ideas. These arise only gradually when, by means of sensuous experience, the phenomena of the outer world affect the central nervous system. But still the little child is wanting in all those differentiated emotions of the soul which the full-grown man acquires only by the long experience of years. From this graduated development of the human soul in every single individual we can, in accordance with the inner causal connection between ontogeny and phylogeny, directly infer the gradual development of the human soul in all mankind, and further, in the whole of the vertebrate tribe. In its inseparable connection with the body, the human soul or mind has also had to pass through all those gradual stages of development, all those various degrees of differentiation and perfecting, of which the hypothetical series of human ancestors sketched in a late chapter gives an approximate representation.

It is true that this conception generally greatly offends

most persons on their first becoming acquainted with the Theory of Development, because more than all others it most strongly contradicts the traditional and mythological ideas, and the prejudices which have been held sacred for thousands of years. But like all other functions of organisms, the human soul must necessarily have historically developed, and the comparative or empirical study of animal psychology clearly shows that this development can only be conceived of as a gradual evolution from the soul of vertebrate animals, as a gradual differentiation and perfecting which, in the course of many thousands of years, has led to the glorious triumph of the human mind over its lower animal ancestral stages. Here, as everywhere, the only way to arrive at a knowledge of natural truth is to compare kindred phenomena, and investigate their development. Hence we must above all, as we did in the examination of the bodily development, compare the highest animal phenomena on the one hand with the lowest animal phenomena, and on the other with the lowest human phenomena. The final result of this comparison is this—that *between the most highly developed animal souls, and the lowest developed human souls, there exists only a small quantitative, but no qualitative difference,* and that this difference is much less than the difference between the lowest and the highest human souls, or than the difference between the highest and the lowest animal souls.

In order to be convinced of this important result, it is above all things necessary to study and compare the mental life of wild savages and of children.[57] At the lowest stage of human mental development are the Australians, some tribes of the Polynesian Papuans, and the Bushmen, Hotten-

tots, and some of the Negro tribes in Africa, and the Tierra del Fuegians in South America. Language, the chief characteristic of genuine men, has with them remained at the lowest stage of development, and hence also their formation of ideas has remained at a low stage. Many of these wild tribes have not even a name for animal, plant, colour, and such most simple ideas, whereas they have a word for every single, striking form of animal and plant, and for every single sound or colour. Thus even the most simple abstractions are wanting. In many of these languages there are numerals only for one, two, and three: no Australian language counts beyond four. This fact seems specially remarkable; for to count up to five, by means of the fingers, appear so simple a method. Very many wild tribes can count no further than ten or twenty, whereas some very clever dogs have been made to count up to forty and even beyond sixty. And yet the faculty of appreciating number is the beginning of mathematics! Nothing, however, is perhaps more remarkable in this respect, than that some of the wildest tribes in Southern Asia and Eastern Africa have no trace whatever of the first foundations of all human civilization, of family life, and marriage. They live together in herds, and their whole mode of life shows much more resemblance to that of wild hordes of apes than to any civilized human community. All attempts to introduce civilization among these, and many of the other tribes of the lowest human species, have hitherto been of no avail; it is impossible to implant human culture where the requisite soil, namely, the perfecting of the brain, is wanting. Not one of these tribes has ever been ennobled by civilization; it rather accelerates their extinction. They have barely

risen above the lowest stage of transition from man-like apes to ape-like men, a stage which the progenitors of the higher human species had already passed through thousands of years ago.[44]

Now consider, on the other hand, the highest stages of development of mental life in the higher vertebrate animals, especially birds and mammals. If, as is usually done, we divide the different activities of the soul into three principal groups—sensation, will, and thought—we shall find, in regard to every one of them, that the most highly developed birds and mammals are on a level with the lowest human beings, or even decidedly surpass them. The *will* is as distinctly and strongly developed in higher animals as in men of character. In both cases it is never actually free, but always determined by a causal chain of ideas. In like manner, the different degrees of will, energy, and passion are as variously graduated in higher animals as in man. The *affections* of the higher animals are not less tender and warm than those of man. The fidelity and devotion of the dog, the maternal love of the lioness, the conjugal love and connubial fidelity of doves and love-birds are proverbial, and might serve as examples to many men. If these virtues are to be called " instincts," then they deserve the same name in mankind. Lastly, with regard to *thought*, the comparative consideration of which doubtless presents the most difficulties, this much may with certainty be inferred—especially from an examination of the comparative psychology of cultivated domestic animals—that the process of thinking here follows the same laws as in ourselves. Experiences everywhere form the foundation of conceptions, and lead to the recog-

nition of the connection between cause and effect. In all cases, as in man, it is the path of induction and deduction which leads to the formation of conclusions. It is evident that in all these respects the most highly developed animals stand much nearer to man than to the lower animals, although they are also connected with the latter by a chain of gradual and intermediate stages. In Wundt's excellent "Lectures on the Human and Animal Soul,"[46] and in Büchner's "Mental Life in Animals,"[57] there are a number of proofs of this.

Now, if instituting comparisons in both directions, we place the lowest and most ape-like men (the Austral Negroes, Bushmen, and Andamans, etc.), on the one hand, together with the most highly developed animals, for instance, with apes, dogs, and elephants, and on the other hand, with the most highly developed men—Aristotle, Newton, Spinoza, Kant, Lamarck, or Goethe—we can then no longer consider the assertion, that the mental life of the higher mammals has gradually developed up to that of man, as in any way exaggerated. If we are to draw a sharp boundary between them, it must be drawn between the most highly developed and civilized man on the one hand, and the rudest savages on the other, and the latter have to be classed with the animals. This is, in fact, the opinion of many travellers, who have long watched the lowest human races in their native countries. Thus, for example, a great English traveller, who lived for a considerable time on the west coast of Africa, says, "I consider the negro to be a lower species of man, and cannot make up my mind to look upon him as 'a man and a brother,' for the gorilla would then also have to be admitted into

the family." Even many Christian missionaries, who, after long years of fruitless endeavours to civilize these lowest races, have abandoned the attempt, express the same harsh judgment, and maintain that it would be easier to train the most intelligent domestic animals to a moral and civilized life, than these unreasoning brute-like men. For instance, the able Austrian missionary Morlang, who tried for many years without the slightest success to civilize the ape-like negro tribes on the Upper Nile, expressly says, "that any mission to such savages is absolutely useless. They stand far below unreasoning animals; the latter at least show signs of affection towards those who are kind towards them, whereas these brutal natives are utterly incapable of any feeling of gratitude."

Now, it clearly follows, from these and other testimonies, that the mental differences between the lowest men and the animals are less than those between the lowest and the highest men; and if, together with this, we take into consideration the fact that in every single human child mental life develops slowly, gradually, and step by step, from the lowest condition of animal unconsciousness, need we still feel offended when told that the mind of the whole human race has in like manner gone through a process of slow, gradual, and historical development? Can we find it "degrading" to the human soul that, by a long and slow process of differentiation and perfecting, it has very gradually developed out of the soul of vertebrate animals? I freely acknowledge that this objection, which is at present raised by many against the pithecoid theory, is quite incomprehensible to me. On this point Bernhard Cotta, in his excellent "Geologie der Gegenwart," very

justly remarks, "Our ancestors may be a great honour to us; but it is much better if we are an honour to them!" [31]

With regard to the human "soul-organ," the brain, the application of the fundamental law of biogeny has been finally established by the most careful empiric observations. The same may be said of its functions, the "activity of the soul." For the development of a function goes hand in hand with the gradual development of every organ. The morphological differentiation of the various parts of the brain corresponds with its physiological separation or "division of labour." Hence, what is commonly termed the "soul" or "mind" of man (consciousness included) is merely the sum-total of the activities of a large number of nerve-cells, the ganglia-cells, of which the brain is composed. Where the normal arrangement and function of these latter does not exist, it is impossible to conceive of a healthy "soul." This idea, which is one of the most important principles of our modern exact physiology, is certainly not compatible with the widespread belief in the "personal immortality" of man. However, this dualistic dogma, which is met with among the lower races of men in the greatest variety of forms, is, in fact, no longer tenable. The wonderful advances made in experimental physiology and psychiatry, as well as in comparative psychology and ontogeny, have, during the last half-century, removed stone after stone from the mighty substructure upon which this dogma stood apparently so unassailably. However, it lost its last hold by the grand biological discoveries of the last two decades, above all by the complete uplifting of the veil which had hitherto concealed the mystery of fertilization. We now know for certain, and can demon-

strate the fact at any moment under the microscope, that the wonderful process of fertilization is nothing more than the commingling of two different cells, the copulation of their kernels. In this process the kernel of the male sperm-cell transmits the individual peculiarities of the father, the kernel of the female egg-cell transmits those of the mother; the inheritance from both parents is determined by the commingling of both kernels, and with it likewise begins the existence of the new individual, the child. It is against all reason to suppose that this new individual should have "an eternal life" without end, when we can minutely determine the finite beginning of its existence by direct observation.

Our Theory of Development explains the origin of man and the course of his historical development in the only natural manner. We see in his gradually ascensive development out of the lower vertebrata, the greatest triumph of humanity over the whole of the rest of Nature. We are proud of having so immensely outstripped our lower animal ancestors, and derive from it the consoling assurance that in future also, mankind, as a whole, will follow the glorious career of progressive development, and attain a still higher degree of mental perfection. When viewed in this light, the Theory of Descent as applied to man opens up the most encouraging prospects for the future, and frees us from all those anxious fears which have been the scarecrows of our opponents.

We can even now foresee with certainty that the complete victory of our Theory of Development will bear immensely rich fruits—fruits which have no equal in the whole history of the civilization of mankind. Its first and

most direct result—the complete reform of Biology—will necessarily be followed by a still more important and fruitful reform of Anthropology. From this new theory of man there will be developed a new philosophy, not like most of the airy systems of metaphysical speculation hitherto prevalent, but one founded upon the solid ground of Comparative Zoology. Just as this new monistic philosophy first opens up to us a true understanding of the real universe, so its application to practical human life must open up a new road towards moral perfection. By its aid we shall at last begin to raise ourselves out of the state of social barbarism in which, notwithstanding the much-vaunted civilization of our century, we are still plunged. For, unfortunately, it is only too true, as Alfred Wallace remarks with regard to this, at the end of his book of travels, " Compared with our wondrous progress in physical science and its practical applications, our system of government, of administering justice, of national education, and our whole social and moral organization remain in a state of barbarism."

This social and moral barbarism we shall never overcome by the artificial and perverse training, the one-sided and defective teaching, the inner untruth and the external tinsel, of our present state of civilization. It is above all things necessary to make a complete and honest return to Nature and to natural relations. This return, however, will only become possible when man sees and understands his true "place in nature." He will then, as Fritz Ratzel has excellently remarked, "no longer consider himself an exception to natural laws, but begin to seek for what is lawful in his own actions and thoughts, and endeavour

to lead a life according to natural laws." He will come to arrange his life with his fellow-creatures—that is, the family and the state—not according to the laws of distant centuries, but according to the rational principles deduced from knowledge of nature. Politics, morals, and the principles of justice, which are still drawn from all possible sources, will have to be formed in accordance with natural laws only. An existence worthy of man, which has been talked of for thousands of years, will at length become a reality.

The highest function of the human mind is perfect knowledge, fully developed consciousness, and the moral activity arising from it. "Know thyself!" was the cry of the philosophers of antiquity to their fellow-men who were striving to ennoble themselves. "Know thyself!" is the cry of the Theory of Development, not merely to the individual, but to all mankind. And whilst increased knowledge of self becomes, in the case of every individual man, a strong force urging to an increased attention to conduct, mankind as a whole will be led to a higher path of moral perfection by the knowledge of its true origin and its actual position in Nature. The simple religion of Nature, which grows from a true knowledge of Her, and of Her inexhaustible store of revelations, will in future ennoble and perfect the development of mankind far beyond that degree which can possibly be attained under the influence of the multifarious religions of the Churches of the various nations,—religions resting on a blind belief in the vague secrets and mythical revelations of a sacerdotal caste. A firm foundation for this religion of Nature is formed by the monistic conviction of the unity of all natural phenomena, the unity of mind

and body, of force and matter, of God and Universe. The different forms of pantheism in which, for more than two thousand years, the greatest minds have laid down their natural conception of the universe, are but different ways of expressing the fundamental thought of Monism.

The Monistic religion of Nature, which, accordingly, we must consider as the true "religion of the Future," will not, like all Church religions, stand opposed to the rational knowledge of nature, but be in perfect harmony with it. And whereas Church religions are founded on deception and superstition, the religion of Nature will be based upon truth and knowledge. And how little the subjection of human reason to the yoke of superstition, and its alienation from nature, is able to make man better and happier, must be evident to all unbiassed minds from the history of all Church religions. During the most flourishing period of the Middle Ages, when Christianity asserted its sovereignty over the whole world, the crudest ignorance, the most offensive barbarity, and the deepest immorality prevailed everywhere. Philosophy, the prince of all the sciences, which, five hundred years before Christ, had—in Heraclitus, Empedocles, and Democritus—sown the seeds for our modern theory of evolution, became, by the dissemination of Roman Catholic dogmas, and the burning piles of the Inquisition, the blind tool of ecclesiastical faith. Not till the mighty advance of natural science during the last century was philosophy, deluded and degraded as it had become, again shown the lost way towards Truth, and its foundation will henceforth remain the monistic theory of development. Future centuries will celebrate our age, which was occupied with laying the foundations of the Doctrine of Evolution,

the highest prize of human knowledge, as the new era in which began a period of human development, rich in blessings,—a period which was characterized by the victory of free inquiry over the despotism of authority, and by the powerful ennobling influence of the Monistic Philosophy.

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APPENDIX.

EXPLANATION OF THE PLATES.

PLATE I. (*Between pages* 188 *and* 189, *Vol. I.*)

History of the Life of the most Simple Organism, a Moneron (Protomyxa aurantiaca). Compare vol. i. p. 189, and vol. ii. p. 67. The plate is a smaller copy of the drawing in my "Monographie der Moneren" (Biologische Studien, 1 Heft, 1870; Taf. 1), of the developmental history of the Protomyxa aurantiaca; I have there also given a detailed description of this remarkable Moneron (pp. 11–30). I discovered this most simple organism in January, 1867, during a stay in Lanzarote, one of the Canary Islands. I found it either adhering to, or creeping about on the white calcareous shells of a small Cephalopod, the Spirula Peronii, which float there in masses on the surface of the ocean, or are thrown up on the shore. The Protomyxa aurantiaca is distinguished from the other Monera by the beautiful and bright orange-red colour of its perfectly simple body, which consists merely of plasson or non-nucleated plasma. The fully developed Moneron is represented in Fig. 11 and 12, very much enlarged. When it is hungry (Fig. 11), there radiate from the surface of the globular corpuscule of plasm, quantities of tree-shaped, branching and mobile threads (pseudo-feet, or pseudo-podia). When, however, the Moneron eats (Fig. 12), the mucous threads become variously connected, form networks and enclose the

extraneous corpuscule which serves as food, which the threads afterwards draw into the interior of the Protomyxa. Thus in Fig. 12 (above on the right), a silicious and ciliated Whip-swimmer (Peridinium) has just been caught by the extended mucous filaments, and has been drawn into the interior of the mucous globule, in which there already are several half-digested silicious infusoria (Tintinoida) and Diatomeæ (Isthmia). Now, when the Protomyxa has eaten and grown sufficiently, it draws in all its mucous filaments (Fig. 15), and contracts into the form of a globule (Fig. 16 and Fig. 1). In this state of repose the globule secretes a simple gelatinous covering (Fig. 2), and after a time subdivides into a large number of small mucous globules (Fig. 3). These soon commence to move, become pear-shaped (Fig. 4), break through the common covering (Fig. 5), and then swim about freely in the ocean by means of a delicate whip-shaped process, like the Flagellata (vol. ii. p. 85, Fig. 14). When they meet a Spirula shell, or any other suitable object, they adhere to it, draw in their whip, and creep slowly about on it by means of form-changing processes (Fig. 6, 7, 8), like Protamœbæ. Like the latter, these small mucous corpuscules take food (Fig. 9, 10), and attain their full-grown form (Fig. 11, 12), either by simple growth or by several of them fusing to form a larger protoplasmic mass (Fig. 13, 14).

PLATES II. AND III. (*Between pages* 334 *and* 335, *Vol. I.*)

Germs or Embryos of four different Vertebrate Animals, namely, Tortoise (*A* and *E*), Hen (*B* and *F*), Dog (*C* and *G*), and Man (*D* and *H*). Fig. *A* and *D*, an early stage of development; Fig. *E* and *H*, a later stage. All the eight embryos are represented as seen from the right side, the curved back turned to the left. Fig. *A* and *B* are seven times enlarged, Fig. *C* and *D* five times, Fig. *E* and *H* four times. Plate II. exhibits the very close blood-relationship between birds and reptiles; Plate III. that between man and the other mammals. A more detailed representation of the embryos of *eight* different Vertebrata (fish,

salamander, tortoise, hen, pig, ox, rabbit, man), and at *three* different stages of development, is given in my "Anthropogenie," 3rd Edition, 1877, p. 290, Plates VI., VII.

PLATE IV. (*Frontispiece to Vol. I.*)

The Hand, or Fore Foot, of nine different Mammals. This plate is intended to show the importance of Comparative Anatomy to Phylogeny, inasmuch as it proves how the internal skeleton of the limbs is continually preserved by *inheritance*, although the external form is extremely changed by *adaptation.* The bones of the skeleton of the hand are drawn in white lines on the brown flesh and skin which surrounds them. All the nine hands are represented in the same position; namely, the wrist (where the arm would be joined to it) is placed above, whilst the ends of the fingers or toes are turned downwards. The thumb, or the first (large) fore toe, is on the left in every figure; the little finger, or fifth toe, is to the right at the edge of the hand. Each hand consists of three parts, namely (i.) the *wrist* (carpus), composed of two cross rows of short bones (at the upper side of the hand); (ii.) the *mid-hand* (metacarpus), composed of five long and strong bones (marked in the centre of the hand by the numbers 1–5); and (iii.) the five *fingers*, or *fore toes* (digiti), every one of which again consists of several (mostly from two to three) *toe-pieces*, or *phalanges.* The hand of *man* (Fig. 1), in regard to its entire formation, stands midway between that of the two large human apes, namely, that of the *gorilla* (Fig. 2), and that of the *orang* (Fig. 3). The fore paw of the *dog* (Fig. 4) is more different, and the hand or breast fin of the *seal* (Fig. 5) still more so. The adaptation of the hand to the movement of swimming, and its transformation into a fin for steering, is still more complete in the *dolphin* (Ziphius, Fig. 6). The extended fingers and bones of the central hand here have remained short and strong in the swimming membrane, but they have become extremely long and thin in the *bat* (Fig. 7), where the hand has developed

into a wing. The extreme opposite of the latter formation is the hand of the *mole* (Fig. 8), which has acquired a powerful spade-like form for digging, with fingers which have become extremely short and thick. What is far more like the human hand than these latter forms, is the fore paw of the lowest and most imperfect of all mammals, the Australian *beaked animal* (Ornithorhynchus, Fig. 9), which in its whole structure stands nearer to the common, extinct, primary form of mammalia, than any known species. Hence man differs less in the formation of the hand from this common primary form than from the bat, mole, dolphin, seal, and many other mammals.

PLATE V. (*Between pages* 344 *and* 345, *Vol. I.*)

Gastrula-formation of the Pond-snail (Lymnæus) and of the Arrow-worm (Sagitta). The gastrulation, which includes the first five germinal stages of the Metazoa, is represented on Plate V. in its simplest and most original form, as the formation of the *Archigastrula* (Fig. 8 and 18); all the germinal forms must be regarded as secondary modifications of this primary form. Fig. 1–10 show the Gastrula-formation of a Mollusc, of the common Pond-snail (Lymnæus), according to the investigations of Carl Rabl; Fig. 11–20 of one of the worm-tribe, the arrow-worm (Sagitta), according to the observations of Gegenbaur and Hertwig. The letters denote the same in all of the figures:—

a. primary intestine (Progaster); *k.* germinal skin (Blastoderm); *o.* primary mouth (Prostoma); *b.* germinal cavity (Blastocœloma); *e.* skin or outer layer (Ectoderma); *c.* body-cavity (Cœloma); *i.* intestinal or inner layer (Entoderma); *p.* skin fibrous layer (Pariental layer); *g.* sexual cells (Gonocyta); *v.* intestinal fibrous layer (Visceral layer).

Fig. 1 and 11, *Ancestral cell* (Cytula) or "fructified egg-cell" (also called "first globule of the cleavage"). Fig. 2 and 12, the cytula dividing into two. Fig. 3–13, dividing into four. Fig. 4–14, its division into eight cleavage-globules or blastomeres. Fig. 5 and 15, *Mulberry-shaped germ* (Morula). Fig. 6

and 16, *Bladder-shaped germ* (Blastula, hollow-globula in cross-section). Fig. 7 and 17, *Hood-shaped germ* (Depula, or depression of the blastula). Fig. 8 and 18, the *Goblet-shaped germ* (Gastrula) in cross-section. Fig. 9—19, *Cœlom-larva* (Cœlomula) in cross-section. Fig. 10–20, *larva* with mouth and anus.

PLATE VI. (*Between pages* 176 *and* 177, *Vol. II.*)

Gastræada of the present day and their nearest kin. The letters signify the same for all the figures :—

a. primary intestine (Progaster) ; *u.* egg-cells ; *o.* primary mouth (Prostoma) ; *p.* cutaneous pores (dermal pores) ; *e.* skin or outer layer (Exoderma) ; *x.* extraneous body (Xenophya), signifying a skeleton ; *i.* intestinal or inner layer (Entoderma).

Fig. 1.—Ammolynthus prototypus. A *sand-sponge* of the simplest kind from the deep sea (skeleton of radiolaria-shells).

Fig. 2.—Cross-section of the same sand-sponge, the lower half of the body.

Fig. 3.—Calcolynthus primigenius. A *calcareous sponge* of the simplest kind (skeleton of three-rayed calcareous spicules). A portion of the body-wall has been removed to show the eggs in the interior.

Fig. 4.—An amœboid egg-cell of the same calcareous sponge.

Fig. 5.—A whip-cell from the intestinal layer of the same sponge.

Fig. 6.—Prophysema primordiale (formerly Haliphysema primordiale), a *Physemarium* of the simplest kind, in longitudinal section.

Fig. 7.—Cross-section of the same Physemarium.

Fig. 8.—Three whip-cells from the intestinal layer of the same Physemarium.

Fig. 9.—Rhopalura Giardii, a freely swimming Cyemarium from the class of the Orthonectida.

Fig. 10.—Cross-section of the same.

Fig. 11.—The common fresh-water polyp (Hydra vulgaris) in a distended state.

Fig. 12.—The same, in a very contracted state.

Fig. 13.—Cross-section of the same Hydra.

Fig. 14.—A whip-cell from the intestinal layer of the same Hydra.

Fig. 15.—Two sperm-threads (whip-cells) of the same Hydra.

Fig. 16.—An amœboid egg-cell of the same Hydra.

PLATE VII. (*Between pages* 186 *and* 187, *Vol. II.*)

A group of Sea-nettles (*Acalephæ or Cnidariæ*) *from the Mediterranean.* On the upper half of the plate is seen a swarm of swimming Medusæ and Ctenophora; in the lower half, a few bunches of corals and hydroid polyps adhering to the bottom of the sea. (Compare the system of the Cnidaria on p. 182, and their pedigree on the opposite page.)

Among the *adhering zoophytes* at the bottom of the sea, there is, below on the right hand, a large coral-colony (1), which is closely akin to the red precious coral (Eucorallium), and like the latter belongs to the group of corals with eight rays (Octocoralla Gorgonida); the single individuals (or persons) of the branching stock have the form of a star with eight radii, consisting of eight tentacles, surrounding the mouth (Octocoralla). Directly below and in front of it (quite below on the right) is a small bush of hydroid polyps (2), from the group of bell-polyps, or Campanariæ. A larger stock of hydroid polyps (3), from the group of tube-polyps, or Tubullariæ, rises, to the left, on the opposite side, with its long thin branches. At its base is spread a stock of silicious sponges (Halichondria) (4), with short, finger-shaped processes. Behind it, to the left, below (5) is a very large marine rose (Actinia), a single individual from the class of six-rayed corals (Hexacoralla). Its low, cylindrical body has a crown of very numerous and large leaf-shaped tentacles. Below, in the centre of the ground (6), is a sea-anemone (Cereanthus), from the group of four-rayed corals (Tetracoralla). Lastly, on a small hill at the bottom of the sea, there rises, on the

right above the corals (1), a cup-polyp (Lucernaria), as the representative of the stalked jelly-fish. Its cup-shaped, stalked body (7) has eight globular clusters of small knotted tentacles on its rim.

Among the *swimming zoophytes*, which occupy the upper half of Plate VII., the hydromedusæ are especially remarkable on account of their alternate generations. Directly above the Lucernaria (7), floats a small tiara jelly-fish (Tiara), whose bell-shaped body has a process like a dome, the form of a papal tiara (8). From the opening of the bell hangs a wreath of very fine and long tentacles. This Tiara is the offspring of a tube-polyp, resembling the adhering Tubularia below on the left (3). Beside this latter, on the left, swims a large but very delicate hair-jelly-fish (Æquorea). Its disc-shaped, slightly arched body is just drawing itself together, and pressing water out of the cavity of the cup lying below (9). The numerous, long, and fine hair-like tentacles which hang down from the rim of the cup are drawn by the ejected water into a conical bunch, which towards the centre turns upwards like a collar, and is thrown into folds. Above, in the middle of the cavity of the cup, hangs the stomach, the mouth of which is surrounded by four lobes. This Æquorea is derived from a small bell-polyp resembling the Campanaria (2). The small, slightly arched cap-jelly (Eucope), swimming above in the centre (10), is likewise derived from a similar bell-polyp. In these three last cases (8, 9, 10), as in the majority of the hydromedusæ, the alternation of generation consists in the freely swimming medusa, arising by the formation of buds (hence by non-sexual generation) from adhering hydroid polyps; these latter, however, originate out of the fructified eggs of the medusæ. Hence the non-sexual, adhering generation of polyps regularly alternates with the sexual, freely swimming generation of medusæ (II., IV., VI., etc.). In other medusæ, on the other hand, the development is a direct one, inasmuch as the eggs of medusæ produce medusæ; for instance, in the case of the elephant-jellies or Geryonida (Carmarina, Fig. 11), in the

larva-jellies or Æginida (Cunina, Fig. 12), and in the phosphorescent jellies (Pelagia, Fig. 14).

Even more interesting and instructive than these remarkable relations are the vital phenomena of the Siphonophora, with their wonderful polymorphism. An example of this is given on Plate VII. in the drawing of the beautiful Physophora (13). This swimming stock or colony of hydromedusæ is kept floating on the surface of the sea by a small swimming-bladder filled with air, which, in the drawing, is seen rising above the surface of the water. Below it is a column of four pairs of swimming bells, which eject water, and thereby set the whole colony in motion. At the lower end of the column of swimming bells is a crown-shaped wreath of curved spindle-shaped sensitive polyps, which also act as a covering, and under the protection of which are hidden the other individuals of the stock (the eating, catching, and reproducing persons).

Finally, the last class of zoophytes, the group of Comb jelly-fish (Ctenophora), has two representatives on Plate VII. To the left, in the centre, between the Æquorea (9), the Physophora (13), and the Cunina (12), is a long and thin band, like a belt (15), winding like a snake; this is the large and splendid Venus Girdle of the Mediterranean (Cestum), the colours of which are as varied as those of the rainbow. The actual body of the animal, which lies in the centre of the long belt, is very small, and constructed exactly like that of the melon-jelly (Cydippe), which floats above to the left (16). On the latter are visible the eight characteristic fringed bands, or ciliated combs, of the Ctenophora, and also two long tentacles which extend right across the page, and are fringed with still finer threads.

PLATES VIII. AND IX. (*Between pages 214 and 215, Vol. II.*)

History of the Development of Star-fishes (*Echinoderma*). The two plates exhibit the peculiar ontogeny of star-fishes which some zoologists regard as metamorphosis, others as an alternation

of generation. The sea-stars (Asterida) are represented by Uraster (*A*), the sea-lilies (Crinoida) by Comatula (*B*), the sea-urchins (Echinida) by Echinus (*C*), and finally, the sea-cucumbers (Holothuriæ) by Synapta (*D*). The successive stages of development are marked by the numbers 1–6.

Plate VIII. represents the individual development of the first and non-sexual generation of Star-fishes, that is, of the *nurses* (usually, but erroneously, called larvæ). These nurses possess the form-value of a simple, unsegmented worm-individual of a bilateral fundamental form. Fig. 1 represents the egg of the four Star-fishes; and it, in all essential points, agrees with that of man and of other animals. As in man, the protoplasm of the egg-cell (the yolk) is surrounded by a thick, structureless membrane (zona pellucida), and contains a globular cell-kernel (nucleus), as clear as glass, which again encloses a darker nucleolus. Out of the fertilized egg of the Star-fish (Fig. *A* 1) there develops, as a rule, in the first place, the Gastrula (Fig. 19, *I*, *K*, p. 158); this changes into a very simple nurse, which has almost the same shape as a wooden shoe (Fig. *A* 2—*D* 2). The edge of the opening of the shoe is bordered by a fringe of cilia, the ciliary movements of which keep the microscopically small and transparent nurse swimming about freely in the sea. This fringe of cilia is marked in Fig. 2–4, on Plate VI., by the narrow alternately light and dark seam. The nurse then, in the first place, forms a perfectly simple intestinal canal for nutrition, with mouth (*o*), stomach (*m*), and anus (*a*). Later, the windings of the fringe of cilia become more complicated, and there arise arm-like processes (Fig. *A* 3—*D* 3). In sea-stars (*A* 4) and sea-urchins (*C* 4) these arm-like processes, which are fringed with cilia, afterwards become very long. But in the case of sea-lilies (*B* 3) and sea-cucumbers (*D* 4), instead of this, the fringe of cilia, which at first, through winding in and out, forms one closed ring, changes subsequently into a succession (4–5) of separate ciliated girdles, one lying behind the other.

In the interior of this curious nurse there then develops, by

a non-sexual process of generation, namely, by the formation of internal buds or germ-buds (round about the stomach), the second generation of Star-fishes, which later on become sexually ripe. This second generation, which is represented on Plate IX. in a fully developed condition, exists originally as a stock or cormus of five worms, connected at one end in the form of a star, as is most clearly seen in the sea-stars, the most ancient and original form of the star-fishes. The second generation, which grows at the expense of the first, appropriates only the stomach and a small portion of the other organs of the latter, but forms for itself a new mouth and anus. The fringe of cilia, and the other parts of the body of the nurse, afterwards disappear. The second generation (*A* 5—*D* 5) is at first smaller or not much larger than the nurse, whereas, by growth, it afterwards becomes more than a hundred times, or even a thousand times, as large.

Plate IX. shows the fully developed and sexually mature animals of the second generation from the mouth side, which, in the natural position of Star-fishes (when creeping at the bottom of the sea), in sea-stars (*A* 6) and sea-urchins (*C* 6), is below, in sea-lilies (*B* 6) above, and in sea-cucumbers (*D* 6) in front. In the centre we perceive, in all the four Star-fishes, the star-shaped, five-pointed opening of the mouth. In sea-stars, from each arm there extend several rows of little sucking feet, from the centre of the under-side of each arm to the end. In sea-lilies (*B* 6), each arm is split and feather-like from its base upwards. In sea-urchins (*C* 6) the five rows of sucking feet are divided by broader fields of spines. In sea-cucumbers, lastly (*D* 6), on the worm-like body it is sometimes only the five rows of little feet, sometimes only the feathery tentacles surrounding the mouth, from five to fifteen (in this case ten), that are externally visible. (Compare Plate XVIII., Fig. 4.)

(PLATES X. AND XI. (*Between pages* 238 *and* 239, *Vol. II.*)

Historical Development of the Crab-fish (Crustacea). The two plates illustrate the development of the different Crustacea from the nauplius, their common germinal form. On Plate XI. six Crustacea, from six different orders, are represented in a fully developed state, whereas on Plate X. the early nauplius stages are given. From the essential agreement between the latter we may, on the ground of the fundamental law of biogeny, with full assurance maintain the derivation of the different Crustacea from a single, common primary form, a long since extinct Nauplius, as was first shown by Fritz Müller in his excellent work "Für Darwin."[16]

Plate X. represents the *early nauplius stages* from the ventral side, so that the three pairs of legs, on the short, simple trunk are distinctly visible. The first of these pairs of legs is simple and unsegmented, whereas the second and third pairs are forked. All three pairs are furnished with stiff bristles, which, through the paddling motion of the legs, serve as an apparatus for swimming. In the centre of the body, the perfectly simple, straight intestinal canal is visible, possessing a mouth in front, and an anal orifice behind. In front, above the mouth, lies a simple, single eye. All the six forms of nauplius entirely agree in all these essential characteristics of organization, whereas the six fully developed forms of Crustacea belonging to them, Plate XI., are extremely different in organization. The differences of the six nauplius forms are confined to quite subordinate and unessential relations in regard to size of body, and the formation of the covering of the skin. If they could be met with in this form in a sexually mature condition, no zoologist would hesitate to regard them as six different species of one genus.

Plate XI. represents those fully developed and sexually mature forms of Crustacea, as seen from the right side, which have ontogenetically (hence also phylogenetically) developed out of the six kinds of nauplius. Fig. *A c* shows a freely swimming fresh-water crab (Limnetis brachyurus) from the order of

the Leaf-foot Crabs (Phyllopoda), slightly enlarged. Of all the still living Crustacea, this order, which belongs to the legion of the Gill-foot Crabs (Branchiopoda), stands nearest to the original, common primary form of nauplius. The Limnetis is enclosed in a bivalved shell, like a mussel. Our drawing (which is copied from Grube) represents the body of a female animal lying in the left shell; the right half of the shell has been removed. In front, behind the eye, we see the two feelers (antennæ), and behind them the twelve leaf-shaped feet of the right side of the body; behind on the back (under the shell), the eggs. Above, in front, the animal is fixed to the shell.

Fig. *B c* represents a common, freely swimming fresh-water crab (Cyclops quadricornis) from the order of Oar-legged crabs (Eucopepoda), highly magnified. In front, below the eye, we see the two feelers of the right side, the foremost of which is longer than the hinder one. Behind these are the gills, and then the four paddling legs of the right side. Behind these are the two large egg-sacks, which, in this case, are attached to the end of the hinder part of the body.

Fig. *C c* is a parasitic Oar-legged crab (Lernæocera esocina), from the order of fish lice (Siphonostoma). These peculiar crabs, which were formerly regarded as worms, have originated, by adaptation to a parasitical life, out of freely swimming, Oar-legged crabs (Eucopepoda), and belong to the same legion (Copepoda. By adhering to the gills on the skin of fish or other crabs, and feeding on the juice of these creatures, they forfeited their eyes, legs, and other organs, and developed into formless, inarticulated sacks, which, on a mere external examination, we should never suppose to be animals. On the ventral side only there exist, in the shape of short, pointed bristles, the last remains of legs which have now almost entirely disappeared. Two of these rudimentary pairs of legs (the third and fourth) are seen in our drawing on the right. Above, on the head, we see thick, shapeless appendages, the lower ones of which are split. In the centre of the body is seen the intestinal canal, which is surrounded by a dark covering of fat. At

its posterior end is the ovary, and the cement-glands of the female sexual apparatus. The two large egg-sacks hang externally (as in the Cyclops, Fig. *B*). Our Lernæocera is represented in half profile, and is copied from Claus.

Fig. *D c* represents a so-called "duck mussel" (Lepas anatifera), from the order of the Barnacle crabs (Cirripedia). These crabs, upon which Darwin has written a very careful monograph, are, like mussels, enclosed in a bivalved, calcareous case, and hence were formerly (even by Cuvier) universally regarded as a kind of mussel, or mollusc. It was only from a knowledge of their ontogeny, and their early nauplius form (*D n*, Plate VIII.), that their crustacean nature was proved. Our drawing shows a "duck mussel" of the natural size, from the right side. The right half of the bivalved shell has been removed, so that the body is seen lying in the left half of the shell. From the rudimentary head of the Lepas there issues a long, fleshy stalk (curving upwards in our drawing); by means of it the Barnacle crab grows on rocks, ships, etc. On the ventral side are six pairs of feet. Every foot is forked and divided into two long, curved, or curled "tendrils" furnished with bristles. Above and behind the last pair of feet projects the thin cylindrical tail.

Fig. *E c* represents a parasitic sack-crab (Sacculina purpurea), from the order of Root-crabs (Rhizocephala). These parasites, by adaptation to a parasitical life, have developed out of Barnacle crabs (Fig. *D c*), much in the same way as the fish-lice (*C c*), out of the freely swimming Oar-legged crabs (*B c*). However, the suppression, and the subsequent degeneration, of all of the organs, has gone much further in the present case than in most of the fish-lice. Out of the articulated crab, possessing legs, intestine, and eye, and which in an early stage, as nauplius (*E n*, Plate VIII.), swam about freely, there has developed a formless, unsegmented sack, a red sausage, which now only contains sexual organs (eggs and sperm) and an intestinal rudiment. The legs and the eye have completely disappeared. At the posterior end is the opening of the genitals. From the mouth grows a

thick bunch of numerous tree-shaped and branching root-like fibres. These spread themselves out (like the roots of a plant in the ground) in the soft hinder part of the body of the hermit-crab (Pagurus), upon which the root-crab lives as a parasite, and from which it draws its nourishment. Our drawing (*E c*), a copy of Fritz Müller's, is slightly enlarged, and shows the whole of the sausage-shaped sack-crab, with all its root-fibres, when drawn out of the body upon which it lives.

Fig. *F c* is a *shrimp* (Peneus Mülleri), from the order of *ten-foot* crabs (Decapoda), to which our river cray-fish, and its nearest relative, the lobster, and the short-tailed shore-crabs also belong. This order contains the largest and, gastronomically, the most important crabs, and belongs, together with the mouth-legged and split-legged crabs, to the legion of the stalk-eyed mailed crabs (Podophthalma). The shrimp, as well as the river-crab, has in front, on each side below the eye, two long feelers (the first much shorter than the second), then three jaws, and three jaw-feet, then five very long legs (the three fore ones of which, in the Peneus, are furnished with nippers, and the third of which is the longest). Finally, on the first five joints of the hinder part of the body there are other five pairs of feet. This shrimp, which is one of the most highly developed and perfect crabs, originates (according to Fritz Müller's important discovery) out of a nauplius (*F n*, Plate VIII.), and consequently proves that the higher Crustacea have developed out of the same form as the lower ones, namely, the nauplius.

PLATES XII. AND XIII. (*Between pages 268 and 269, Vol. II.*)

Blood-relationship between the Vertebrata and the Invertebrata. It is definitely established by Kowalewski's important discovery, which was confirmed by Kupffer, that the ontogeny of the lowest vertebrate animal—the Lancelet, or Amphioxus—agrees in all essential outlines completely with that of the invertebrate Sea-squirts, or Ascidians, from the class of Sea-sacks, or Tunicata. On our two plates, the Ascidia is marked

by *A*, the Amphioxus by *B*. Plate XIII. represents these two very different animal-forms in a *fully developed* state, as seen from the *left side*, the end of the mouth above, the opposite end below. Hence, in both figures the dorsal side is to the right, the ventral to the left. Both figures are slightly magnified, and the internal organization of the animals is distinctly visible through the transparent skin. The full-grown Ascidia (Fig. *A* 6) grows at the bottom of the ocean, from whence it cannot move, and clings to stones and other objects by means of peculiar roots (*w*) like a plant. The full-grown Amphioxus, on the other hand (Fig *B* 6), swims about freely like a small fish. The letters on both figures indicate the same parts: (*a*) orifice of the mouth; (*b*) orifice of the body, or porous abdominalis; (*c*) dorsal rod, or chorda dorsalis; (*d*) intestine; (*e*) ovary; (*f*) oviduct (same as the sperm-duct); (*g*) spinal marrow; (*h*) heart; (*i*) blind-sac of the intestine; (*k*) gill basket (respiratory cavity); (*l*) cavity of the body; (*m*) muscles; (*n*) testicle (in the ascidia united with the ovary into a hermaphrodite gland); (*o*) anus; (*p*) genital orifice; (*q*) well-developed embryos in the body cavity of the Ascidia; (*r*) rays of the dorsal fin of the Amphioxus; (*s*) tail-fin of the Amphioxus; (*w*) roots of the Ascidia.

Plate XII. shows the *Ontogenesis*, or the individual development of the *Ascidia* (*A*) and the *Amphioxus* (*B*) in five different stages (1–5). Fig. 1 is the egg, a simple cell like the egg of man and all other animals (Fig. *A* 1 the egg of the ascidia, Fig. *B* 1 the egg of the amphioxus). The actual cell-substance, or the protoplasm of the egg-cell (*z*), the so-called yolk, is surrounded by a covering (cell-membrane, or yolk-membrane), and encloses a globular cell-kernel, or nucleus (*y*),—the latter, again, contains a kernel-body, or nucleolus (*x*); when the egg begins to develop, the egg-cell first subdivides into a number of cells (Fig. *A* 2, *B* 2, into four, Fig. *A* 3, *B* 3, into eight cells, etc.). Out of the globular heap of cells (Morula) there generally arises the Gastrula (*A* 4, *B* 4). (See Plate V.) Its intestinal cavity (*d* 1) opens by the primary mouth (*d* 4). Its wall of

cells, the intestinal layer (*d* 2), is separated from the dermal layer by the remainder of the cavity (*l*). Fig. *A* 5 represents the larva of the ascidia, Fig. *B* 5 that of the amphioxus, as seen from the left side in a somewhat more advanced state of development. The orifice of the intestine (*d* 1) has closed. The dorsal side of the intestine (*d* 2) is concave, the ventral side (*d* 3) convex. Above the intestinal tube, on its dorsal side, the neural tube, the beginning of the spinal marrow, is being formed; its cavity still opens externally in front (*g* 2). Between the spinal marrow and the intestine has arisen the spinal rod, or chorda dorsalis (Notochord) (*c*), the axis of the inner skeleton. In the larva of the ascidia this rod (*c*) proceeds along the long rudder-tail, a larval organ, which is cast off in later transformation. Yet there still exist some very small ascidiæ (Appendicularia) which do not become transformed and adherent, but which through life swim about freely in the sea by means of their rudder-tail.

The ontogenetic facts which are systematically represented on Plate XII. and which were first discovered in 1867, deserve the greatest attention, and, indeed, cannot be too highly estimated. They fill up the gap which, according to the opinion of older zoologists, existed between the vertebrate and the so-called "invertebrate" animals. This gap was universally regarded as so important and so undeniable, that even eminent zoologists, who were not disinclined to adopt the theory of descent, saw in this gap one of the chief obstacles against it. Now that the ontogeny of the amphioxus and the ascidia has set this obstacle completely aside, we are for the first time enabled to trace the pedigree of man beyond the amphioxus into the many-branching tribe of "invertebrate" worms, from which all the other higher animal tribes have originated.

PLATES XIV. AND XV. (*Between pages* 78 *and* 79, *Vol. II.*)

Fundamental Forms of Protista (*Plate XIV. Primary Plants, Plate XV. Primary Animals*). These two plates explain the

phenomena of Resemblance or Convergence (vol. i. p. 314), the origin of similar forms in very different groups that are not related by blood. They at the same time give a survey of the geometrical regularity of the fundamental forms met with among very many of the Protista.

Plate XIV.

Primary Plants, or Protophyta (Diatomeæ and Cosmariæ).

Fig. 1.—Rhadosphæra Challengeri, a many-rayed Calcocyte.

Fig. 2.—Biddulphia reticulata, a two-rayed Diatom.

Fig. 3.—Triceratium grunowianum, a three-rayed Diatom.

Fig. 4.—Phycastrum quadriradiatum, a four-rayed Cosmarian.

Fig. 5.—Phycastrum quinqueradiatum, a five-rayed Cosmarian.

Fig. 6.—Micrasterias hexactinias, a six-rayed Cosmarian.

Fig. 7.—Phycastrum denticulatum, a three-rayed Cosmarian.

Fig. 8.—Stictodiscus radfordianus, an eight-rayed Diatom.

Fig. 9.—Amœboid stage of a Protophyte.

Fig. 10.—Its transition into a Flagellate stage.

Fig. 11–13.—A most simple one-celled plant (Green Alga of the Palmellaria-group) in the act of dividing (Fig. 12 dividing into two, Fig. 13 dividing into four).

Fig. 14.—A green Whip-swimmer (vegetable Flagellate) containing chlorophyll.

Fig. 15.—Its division into four, in a state of rest (forming tetra-spores).

Plate XV.

Primary Animals (Protozoa) from the Class of the Radiolaria.

Fig. 1.—Oroscena Gegenbauri, a many-rayed Phæodarian.

Fig. 2.—Amphirhopalum echinatum, a two-rayed Discoid.

Fig. 3.—Hymeniastrum Euclidis, a three-rayed Discoid.

Fig. 4.—Histiastrum quadrigatum, a four-rayed Discoid.

Fig. 5.—Pentinastrum asteriscus, a five-rayed Discoid.

Fig. 6.—Hexacolpus nivalis, a six-rayed Acantharian.

Fig. 7.—Hexapyle dodecantha, a three-rayed Discoid.

Fig. 8.—Heliosestrum medusinum, an eight-rayed Discoid.

Fig. 9.—Amoiboide stage of a Protozon.

Fig. 10.—Its transition into a Flagellate.

Fig. 11–13.—A Xanthella or yellow cell (Symbiont of the Radiolaria, from the group of the Palmellaria) in the act of dividing (Fig. 12 halving, Fig. 13 quartering).

Fig. 14.—A colourless (free from chlorophyll) Flagellate (animal Flagellate).

Fig. 15.—Its dividing into four, in a state of rest (forming tetra-spores).

Plate XVI. (*Between pages 92 and 93, Vol. II.*)

Deep-sea Radiolaria of the British Challenger Expedition. The class of Radiolaria shows a much greater wealth in difference and variety of fundamental forms than any other class of the organic world. The species represented on Plates XV. and XVI. give some of the most important typical forms. See, also, my "Kingdom of the Protista" (1878); my "Monograph of the Radiolaria" (1862), with a map containing 35 plates; and the Challenger Report (1887), with 140 plates. All the forms represented here are invisible to the naked eye, and are greatly magnified.

Fig. 1.—*Actissa primordialis* (order of the Colloidea). A globular cell (central capsule), with a central cell-kernel, is surrounded by several small "yellow cells," and radiates many cell-threads (pseudopodia).

Fig. 2.—*Hexancistra quadricuspis* (order of the Sphæroidea). A trellised ball (superficial shell) with central ball (marrow-shell). Six spicules (all with four points) stand in three longitudinal meridian-plains.

Fig. 3.—*Saturnulus planeta* (order of the Sphæroidea). A trellised ball (superficial shell) with central ball (deep-seated shell). Right round it is an equatorial flinty ring (connected with it by two staves lying in an axis), similar to the equatorial nebulous ring that runs round the planet Saturn.

Fig. 4.—*Heliocladus furcatas* (order of the Discoidea). A lens-shaped latticed ball (cortical or superficial shell) with a central ball (medullary or deep-seated shell.) From the equator or from the edge of the biconvex lens radiate numerous flinty spicules which are forked.

Fig. 5.—*Tricanastrum Wyvillei* (order of the Discoidea). From a central circular disc, proceed four arms forming a flat rectangular cross, the end of every arm being divided into three pieces. Fine threads (pseudopodia) radiate all round from the central capsule.

Fig. 6.—*Cœlodendrum Challengeri* (order of the Phædaria). The globular central capsule is enclosed by two hemispheres standing opposite each other (unconnected), each of which bears three arboriform, branching hollow silicious tubes. From the brownish black mass of pigment, which surrounds the central capsule, radiate numerous fine threads (pseudopodia).

Fig. 7.—*Acanthostephanus corona* (order of the Stephoidea). Three spiculate flinty hoops, standing in three successive horizontal plains, connected in such a way that they form a crown of thorns.

Fig. 8.—*Cinclopyramis Murrayana* (order of the Cyrtoidea). A nine-sided pyramid, the nine sides being connected by a number of horizontal cross-bars. An extremely fine trellis-work fills the quadrangular meshes formed by the cross-bars.

Fig. 9.—*Eucecryphalus Huxleyi* (order of the Cyrtoidea). A flat conical latticed shell, with small head-shaped process, and a number of long flinty spicules.

Fig. 10.—*Dictyopodium Moseleyi* (order of the Cyrtoidea). A high conical latticed shell with three limbs, top spicule, and three long little feet, which are broken up into a network at their ends.

Fig. 11.—*Diploconus Saturni* (order of the Acantharia). A double ball, like a sand-clock, or egg-glass, the axis of which is formed by a strong quadrangular spicule, prominent and pointed at both ends; from the centre radiate smaller spicules.

Fig. 12.—*Lithoptera Darwini* (order of the Acantharia). In

the middle is a cross-shaped central capsule. The flinty skeleton consists of twenty spicules (according to Müller's law of dividing the spicula), of sixteen smaller and four larger ones; the latter lie in the equatorial plain, and have four trellis-plates at the end, like the wings of a windmill.

PLATE XVII. *(Between pages* 128 *and* 129, *Vol. II.)*

Fern Forest of the Coal Period. This hypothetical sketch of the landscape, a long since vanished period of the earth's history, has been drawn up and restored from the numerous and well-preserved fossils from that age, much in the same way as was first done by the genial botanist Franz Unger, in his beautiful "Pictures, illustrative of the Primæval World," and subsequently by Oswald Heer, in his "Primæval World of Switzerland," and many others. The plants which composed this primæval forest of the Coal period belong principally to the group of the Prothallota, from the main class of the *Ferns* (*Filicinæ*). On the left side of the little picture, in the foreground below, rise the bent, candelabra-shaped bunches (closely covered with scaly leaflets) of some club-mosses (Lycopodiaceæ), from the class of the *Scale-ferns* (*Selagineæ*). High above them, on the left, rise the gigantic, leafless, fluted columns of several naked Horse-tails (Equisetaceæ), from the class of the Shaft-ferns (*Calamariæ*); at the top they have a cone-shaped spore-holder. To the right, at the back, are seen the pretty larch-like slender trunks of the *Giant Reeds* (*Calamiteæ*), with regularly arranged whorls of needles. On the other side, on the right of the little picture, all the other plants are outstripped by the mighty forked and branching *Scale-trees* (*Lepidodendreæ*), the trunks of which were neatly coated with scales. These trees are among the most important and grandest forms of the *Scale-ferns* (*Selagineæ*). Their forked branches have palm-like crowns of leaves; their scaled trunks are partially covered with parasitical frondose ferns. To the right below, in the

foreground, are various *Frondose Ferns*, with pinnate or pinnulated leaves; the latest fronds in the centre of the clusters are still unrolled. They, like the palm-shaped *Fern-trees* seen in the background, represent the division of frondose ferns (*Pterideæ*), so rich in forms. Finally, the class of *aquatic ferns* (Rhizocarpeæ) is represented by a number of small Filicinæ growing down at the edge of the water, or rising up out of it.

Plates XVIII. and XIX. (*Between pages* 166 *and* 167, *Vol. II.*)

Nervous System of the Metazoa Tribe. The figures are all given more or less schematically; the central nervous system is marked in red.

The letters in all the figures indicate the same: *a.* Eye. *b.* Otic bladder. *c.* Cœlom (body-cavity). *d.* Intestine. *e.* Entoderm. *f.* Foot. *g.* Gonad (sexual gland). *h.* Skin. *i.* Entoderm. *k.* Gills. *l.* Mantle. *m.* Muscles. *n.* Nerve-centre. *o.* Mouth. *p.* Œsophagus (Pharynx). *q.* Shell. *r.* Renal tube (Nephridium). *s.* Sensory organs. *t.* Tentacle (feeler). *u.* Cord. *v.* Chamber of the heart (ventricle). *w.* Antechamber of the heart (atrium). *x.* Ampulla. *y.* Nose. *z.* Anus.

Plate XVIII.

Cœlenterata, Echinoderma, and Articulata.

Fig. 1.—A *Gastræad* (*Gastræa, Prophysema*) in cross-section. *e.* Exoderm (outer germinal layer, occupies the place of the nervous system). *i.* Entoderm (inner germinal layer, surrounds the intestinal cavity, *d*).

Fig. 2.—A *Sponge* (*Spongia*) in cross-section. A number of ciliated chambers (*i*), all of the form-value of a Gastræa (Fig. 1), adhere to the branches of canals which empty themselves into the central cavity. Skin perforated by pores. No nervous system.

Fig. 3.—A *Medusa* (*Ephyra*), from the tribe of the Seanettles (Cnidaria). Lower surface view. The central mouth-cross (*o*) denotes the four rays. I. Order (Perradii); the four egg-stacks (*g*) the rays. II. Order (Interradii). On the rim eight tentacles (*t*) in the rays. III. Order (Adradii), right round the nerve-ring (*n*), with eight sensory organs (*s*).

Fig. 4.—A *Sea-star* (*Asterid*), from the tribe of the Starfish (Echinoderma). Lower surface view. The central mouth is surrounded by a five-cornered nerve-ring, from the five corners of which radiate ventral (perradiale) nerve-bands (*n*) into the five articulated arms. Between these five pairs interradial. Sexual glands (*g*). At the point of every arm an eye (*a*).

Fig. 5.—*Cross-section of the arm of a Sea-star* (Fig. 4). *n.* Radial nerve. *f.* Feet connected with little bladders (*x*). *c.* Body-cavity (cœlom).

Fig. 6.—*Cross-section of a Round Worm* (*Nematod*), from the tribe of Helminthes. *d.* Intestine. *c.* Body-cavity. *m* 4. Four longitudinal muscles. *m* 1. Ring-muscles. *n* 1. Dorsal nerve-stem. *n* 2. Ventral nerve-stem. *r.* Renal tubes (side channels right and left). *h.* Skin.

Fig. 7.—A *Bristle-footed Worm* (*Chætopod*), from the tribe of Ring-worms (Annelida). *n.* Ventral marrow. *a.* Eyes. *f.* Foot-stumps (Parapodia).

Fig. 8.—*Cross-section of a Bristle-footed Worm* (Fig. 7). *d.* Intestine. *n.* Ventral marrow. *v* 1. Dorsal vesicle. *v* 2. Ventral vesicle. *m* 1. Dorsal muscles. *m* 2. Ventral muscles. *f* 1. Dorsal feet. *f* 2. Ventral feet. *c.* Body-cavity. *r.* Renal tubes (looped canals). *k.* Gills.

Fig. 9.—*Cross-section of the breast of a River Crab* (*Astacus*), from the tribe of the Encrusted Animals (Crustacea). *d.* Intestine. *n.* Ventral marrow. *g.* Sexual gland. *v.* Dorsal vessel. *m* 1. Dorsal muscles. *m* 2. Ventral muscles. *f.* Basis of the legs. *k.* Gills. *h.* Epithelial coat of mail.

Fig. 10.—A *Centipede* (*Scolopendra*), from the tribe of the Tracheata, air-breathing Animals. *n.* Ventral marrow. *f.* Articulated feet. *t.* Feelers (Antennæ).

Fig. 11.—A *Bee* (*Apis*), from the tribe of Tracheata, air-breathing Animals. *n*. Ventral marrow. *n* 1. Brain. *n* 2. Gullet-ring. *a*. Eyes. *t*. Antennæ. *f* 1, *f* 2, *f* 3. The three pairs of legs. *f* 4, *f* 5. The two pairs of wings.

Plate XIX.

Worms, Molluscs, and Vertebrates.

Fig. 12.—A *Gliding Worm* (*Turbellarium*), from the tribe of Flat-animals (Platodes). *d*. Intestine. *o*. Mouth. *n*. Brain-ganglion (upper gullet knot). *r*. Renal tubes.

Fig. 13.—An *Ichthydina* (*Chætonotus*), from the tribe of Worm-animals (Helminthes). *u*. Brain-ganglion. *o*. Mouth. *p*. Gullet. *d*. Intestine. *z*. Anus. *x*. Renal tubes.

Fig. 14.—A *Round-worm* (*Nematod*), from the tribe of Helminthes. *d*. Intestine. *n*. Nerve-stems. (Compare Fig. 6.)

Fig. 15.—Cross-section of an *Arrow-worm* (*Sagitta*), from the tribe of Helminthes. *d*. Intestine. *c*. Body-cavity. *m*. Longitudinal muscles. *h*. Epidermis. *n*. Ganglions (ventral knot of the œsophagus).

Fig. 16.—Ventral aspect of a *Snail* (*Gastropod*), from the tribe of Molluscs. *o*. Mouth, surrounded by the ganglions of the œsophagus (*n*). *t*. Tentacles. *a*. Eyes. *f*. Foot. *k*. Gills. *l*. Mantle.

Fig. 17.—Cross-section of a *Snail* (Fig. 15). *q*. Shell. *l*. Mantle. *k*. Gills. *f*. Foot. *n*. Foot-ganglions. *c*. Body-cavity. *d*. Intestine. *v*. Chamber of the heart. *w*. Ante-chamber of the heart.

Fig. 18.—Cross-section of a *Mussel* (*Acephala*), from the tribe of Molluscs. Letters as in the preceding figure.

Fig. 19.—An *Appendicaria* (*Copelata*), from the tribe of Tunicates. *o*. Mouth. *p*. Gullet. *k*. Gill-clefts. *d*. Intestine. *m*. Muscles. *u*. Cord. *g*. Sexual glands (*g* 1 female, *g* 2 male).

Fig. 20.—Cross-section of an *Ascidia-larva*, from the tribe of Tunicates. *h*. Epithelium. *m*. Muscles. *n*. Nerve-tube

(dorsal medulla tube). *u*. Cord. *d*. Intestine. *c*. Body-cavity. *g*. Sexual glands.

Fig. 21.—A *Fish* (*Selachius*), from the tribe of Vertebrates. *n*. Five brain-bladders and dorsal marrow. *y*. Nose. *a*. Eye. *b*. Auricular bladder. *k*. Gill-clefts. *f* 1. Breast-fins. *f* 2. Ventral fins.

Fig. 22.—A *Salamander* (*Amphibium*), from the tribe of Vertebrates. Letters as in Fig. 21. *f* 1. Fore feet. *f* 2. Hind feet.

Fig. 23.—Cross-section of a Fish (Fig. 20). Letters as in Fig. 20. *g*. Sexual glands.

PLATE XX. (*Frontispiece to Vol. II.*)

Hypothetical Sketch of the Monophyletic Origin and the Diffusion of the Twelve Species of Men over the earth (see p. 441 and p. 445). The *hypothesis* here graphically sketched of course only claims an entirely *provisional value*, as in the present imperfect state of our anthropological knowledge it is simply intended to show how the distribution of the human species, from a single primæval home, may be *approximately* indicated. The probable primæval home, or "Paradise," is here assumed to be South-Western Asia. But it is also very possible that the hypothetical "cradle of the human race" lay further to the east, further to the west, or more south. Future investigations, especially in comparative anthropology and palæontology, will, it is to be hoped, enable us to determine the probable position of the primæval home of man more definitely than it is possible to do at present.

If, in opposition to our monophyletic hypothesis, the polyphyletic hypothesis—which maintains the origin of the different human species from several different species of anthropoid ape—be preferred and adopted, then, from among the many possible hypotheses which arise, the one deserving most confidence seems to be that which assumes a double pithecoid root for the human race, namely, an Asiatic and an African root. For it is a very

remarkable fact, that the African man-like apes (gorilla and chimpanzee (are characterized by a distinctly long-headed, or dolichocephalous, form of skull, like the human species peculiar to Africa (Hottentots, Caffres, Negroes, Nubians). On the other hand, the Asiatic man-like apes (especially the small and large orang), by their distinct, short-headed, or brachycephalous, form of skull, agree with human species especially characteristic of Asia (Mongols and Malays). Hence, one might be tempted to derive the latter (the Asiatic man-like apes and primæval men) from a common form of brachycephalous ape, and the former (the African man-like apes and primæval men) from a common dolichocephalous form of ape.

In any case, tropical Africa and southern Asia (and between them Lemuria (?) which perhaps formerly connected them) are those portions of the earth which deserve the first consideration in the discussion as to the primæval home of the human race; America and Australia are, on the other hand, entirely excluded from it. Even Europe (which is in fact but a western peninsula of Asia) is scarcely of any importance in regard to the "Paradise question."

It is self-evident that the migrations of the different human species from their primæval home, and their geographical distribution, could be indicated on our Plate XX. only in a very general way, and in the roughest lines. The numerous migrations of the many branches and tribes in all directions, as well as the very important re-migrations, had to be entirely disregarded. In order to make these latter in some degree clear, our knowledge would, in the first place, need to be much more complete, and secondly, we should have to make use of an atlas with a number of plates showing the various migrations. Our Plate XX. claims no more than to indicate, in a very general way, the approximate geographical dispersion of the twelve human species as it existed in the fifteenth century (before the general diffusion of the Indo-Germanic race), and as it can be sketched out approximately, so as to harmonize with our hypothesis of descent. The eographical barriers to diffusion (mountains, deserts, rivers,

straits, etc.) have not been taken into consideration in this general sketch of migration, because, in earlier periods of the earth's history, they were quite different in size and form from what they are to-day. The gradual transmutation of catarhine apes into pithecoid men probably took place in the tertiary period in the hypothetical Lemuria, and the boundaries and forms of the present continents and oceans must then have been completely different from what they are now. Moreover, the mighty influence of the ice period is of great importance in the question of the migration and diffusion of the human species, although it as yet cannot be more accurately defined in detail. I here, therefore, as in my other hypotheses of development, expressly guard myself against any dogmatic interpretation; they are nothing but *first attempts.*

INDEX.

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